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## Beyond prototypes: Enabling innovation in technology-enhanced learning

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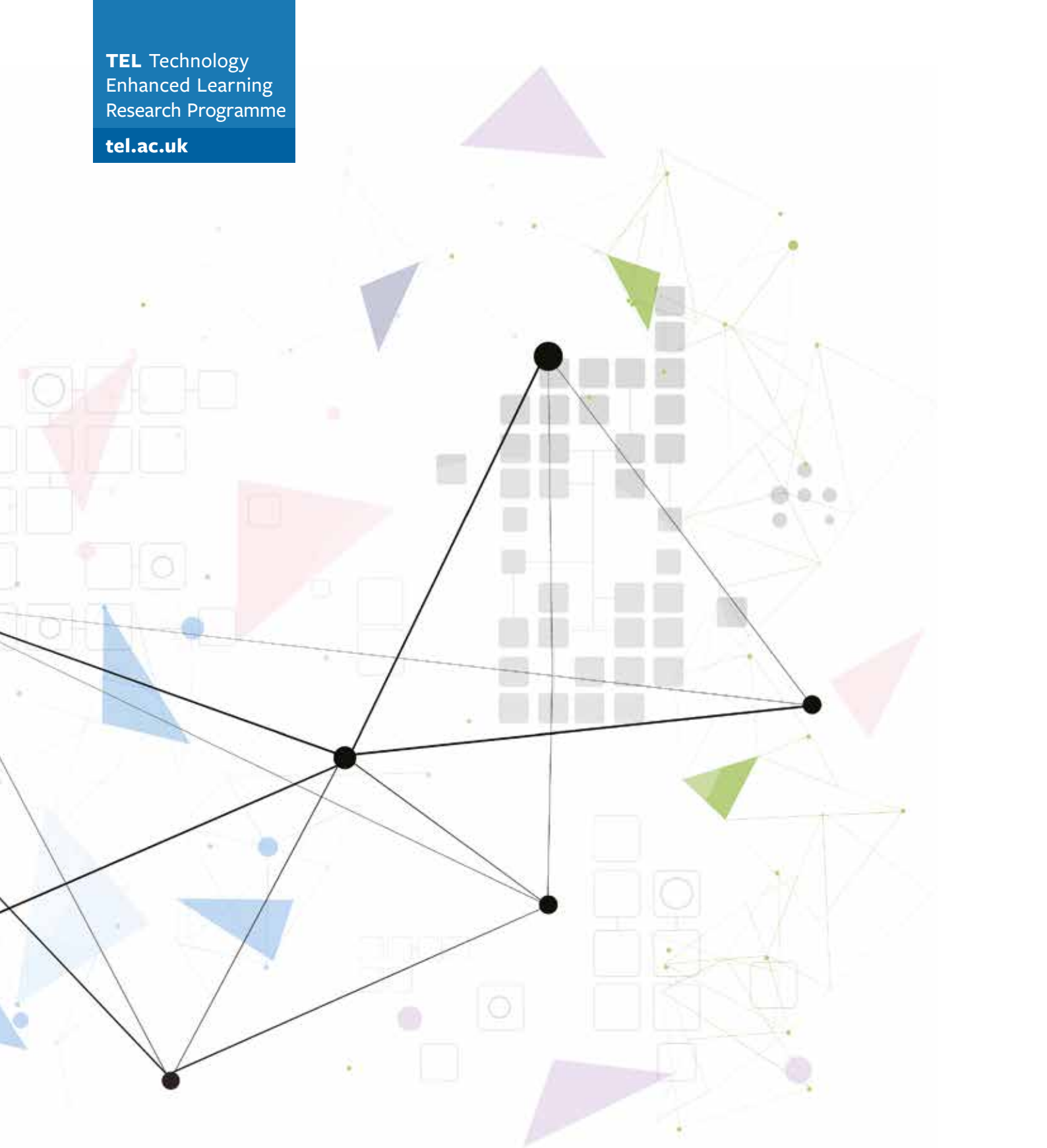
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# BEYOND PROTOTYPES

Enabling innovation in technology-enhanced learning



beyondprototypes.com

**TEL** Technology Enhanced Learning  
Research Programme **tel.ac.uk**



**EPSRC**  
Pioneering research  
and skills

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# THE TEL RESEARCH PROGRAMME (TEL)



The TEL research programme, which ran from 2007 to 2013, has generated some substantial gains in our understanding of how to design and deploy technologies for learning.

These findings, together with the growing field of technology-enhanced learning internationally, are witnessing the growth of TEL research into a vibrant academic field, extending throughout the UK and beyond. Yet there is a surprising failure to translate the findings, prototypes and outputs of projects into commercial products and services that individually and collectively achieve radical change in the quality of teaching and learning.

This difficulty seems part of a general problem of translating innovation in the laboratory (or classroom or school) into commercial gain:

A key recurring issue that has been raised in the Science and Technology Committee's previous inquiries is the difficulty of translating research into commercial application, particularly the lack of funding—the so-called “valley of death”. (Commons Select Cttee, 2011).

The field of Technology Enhanced Learning, despite some notable exceptions, is rife with results that never made it across the valley of death. In the TEL research programme, there were some exciting and innovative examples of working prototypes that solved significant research problems. Yet few of these projects have successfully taken their prototypes to market. Three of the eight funded TEL projects achieved success in gaining follow-on funding from the ESRC specifically earmarked for the achievement of “impact”, although it is too soon to know if and how such impact will be achieved, and more generally, the relationship between impact and the commercial exploitation of projects' outputs. In general, despite the fact that all projects successfully designed and built effective prototypes of systems: the question is how to move from prototype to product.

This report addresses this issue head-on from an interdisciplinary perspective that brings together experts in diverse relevant fields including educational technology, organizational behavior, innovation dynamics. I am grateful to the authors and all those who gave their time to help clarify these difficult and important issues.

A handwritten signature in black ink, appearing to read 'Richard Noss'.

**Prof Richard Noss**

Director, Technology Enhanced Learning Research Programme.  
London Knowledge Lab | Institute of Education | University of London

<sup>1</sup><http://www.parliament.uk/business/committees/committees-a-z/commons-select/science-and-technology-committee/news/111215-new-inquiry---bridging/>

# EXECUTIVE SUMMARY

The *Beyond Prototypes* report provides an in-depth examination of the processes of innovation in technology-enhanced learning (TEL).



It sets out what can be done to improve the process of moving from academic research and innovative prototypes to effective and sustainable products and practices. In doing so, it shows that technological development is only a small part of the picture. Significant and lasting TEL innovation requires long-term shifts in practice. These shifts are not confined to the classroom or training environment; they require alterations to many different elements of the education system. In order to make these shifts, different communities and groups need to work creatively together over time, so policymakers and funders should plan for engagement with teams able to initiate, implement, scale and sustain long-term innovation.

An expert multidisciplinary team carried out the research underpinning this report. Initial analysis of the field of TEL research, development and policy was used to select key examples of TEL innovation for detailed study. Innovation was taken to be the practical implementation of new ideas and technologies with the intention of having an observable impact on teaching and/or learning. The initial phase included systematic analysis of data collected from in-depth interviews with key figures from research and industry. Each member of the research team brought substantial personal expertise to the research process, enabling them to set the findings within a broader context. This was a strength of the study, allowing team members to link their analysis not only to the field of educational technology but also to understandings developed in the fields of organisation behaviour and innovation dynamics.

This executive summary introduces the four key insights described

in the report, links each with recommendations to enable successful TEL innovation and, finally, outlines the structure of the report.

## **Key insight 1: The TEL Complex**

Technology-enhanced learning consists of much more than a set of research-informed products. It is a complex system, which includes communities, technologies and practices that are informed by pedagogy (the theory and practice of teaching, learning and assessment). The many elements of the ‘TEL Complex’ must all be taken into account as an innovation is designed, developed and embedded. At the heart of the TEL Complex is a vision of how learning may be enhanced by the use of technology. This vision requires the development or adaptation of technology over time in order to support a pedagogical approach.


Concurrent implementation of pedagogy and technology requires consideration of current practices, including the activities and expectations of learners and teachers. Less obviously, implementation must also take into account practices related to areas as diverse as local and national assessment criteria, health and safety, staff training, administration and provision of technical support. In order to understand these, researchers need to consider the ecology and technical context into which an innovation is to be introduced. To do this, they must be able to work effectively with diverse other communities, particularly learners, teachers and technology developers.

This innovation work takes place in a wider setting that includes the local, national and international environment. Research and education

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## Look beyond product development and pay close attention to the entire process of implementation.

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are carried out within a context that is shaped by regional and national policy, by funding constraints, and by the need to generate sufficient revenue to ensure that an innovation is sustainable even when short-term funding has run out. A successful process of innovation pays attention to these high-level issues as well as to issues that can be shaped and controlled locally.

**Summary:** TEL involves a complex system of technologies and practices. In order to embed significant TEL innovation successfully, it is necessary to look beyond product development and pay close attention to the entire process of implementation.

**Recommendations:** Policy and funding should support changes in pedagogy and practice, as well as the technological developments that will support these. Project teams should be encouraged to identify the elements that must be taken into account in order to enable sustainable implementation of an idea or prototype in the context of a vision of the enhancement of learning. In order to do this, researchers need to engage with the individuals and communities that will play a role in the implementation process.

### **Key insight 2: Persistent intent**

The diverse nature of the TEL Complex means that a linear model of innovation in which research findings are applied and then adopted is rarely appropriate within the education system. Success in TEL is associated with ‘persistent intent’ – efforts by a group of vision-enactors to develop inspirational ideas and turn them

into products and practices over an extended period of time. This requires both long-term commitment and focused action. Teams of researchers need persistent intent in order to develop their work over time with a shared educational goal in mind. Many different academic and business-based research projects may be aligned in order to work towards the same educational goal.

Persistent intent motivates researchers to work closely with the communities that will be involved in implementation, developing a shared vision that is owned not only by the project team, but also by those who will take it forward once the research programme is complete and the development team has left. To carry out this work successfully, researchers need opportunities to develop the skills that will enable them to bridge the gaps between those different groups.

**Summary:** Significant innovations are developed and embedded over periods of years rather than months. Sustainable change is not a simple matter of product development, testing and roll-out.

**Recommendations:** Policy and funding should take into account the need for extended development. There should be capacity to support individuals and teams to engage in long-term projects capable of turning inspirational ideas into fully embedded products and practices. Researchers and developers should be encouraged to plan for sustainability. The implementation and success of plans for sustainability should be evaluated.

### **Key insight 3: Bricolage**

The work involved in successful TEL innovation can be characterised as ‘bricolage’. This is a productive and creative innovation process

that involves bringing together and adapting technologies and pedagogies, experimentation to generate further insights and a willingness to engage with local communities and practices. Bricoleurs do not start a project and then consider which tools and materials will be required to achieve their goals. Instead, they review their available tools and resources and work out how to use them to achieve their goal or something close to their goal.

Bricolage is a practical process of innovation. It may be informed by a deep understanding of theory and underpinning research, but does not rely solely on a theoretical model of what should work. It engages with relevant communities to ensure that innovation works in practice and in context. Bricoleurs pay attention to the restrictions and constraints of a situation, and take steps to overcome or compensate for them. Through creative reinterpretation and arrangement of local practices and resources, they can enable new possibilities.

Successful TEL innovators, both in academia and in business, are bricoleurs who achieve educational goals by bringing together pedagogic approaches, diverse technological elements, frameworks and social practices. If TEL innovation is to be embedded successfully, bricoleurs need to be able to understand and take into account the perspectives of different stakeholders, and to build links between the experiences and knowledge of different communities. Inter-disciplinary collaboration will involve education theorists, policy makers, software and technology developers, teachers, learners and other practitioners, all with a shared intent to move ideas across boundaries and to explore new approaches to learning and teaching.

**Summary:** TEL innovation is a process of bricolage. This process includes informed and directed exploration of the technologies and practices required to achieve an educational goal. It involves experimentation to generate fresh insights, and a creative use of available resources. It also requires engagement with a range of communities and practices.

**Recommendations:** Policy and funding should encourage the development of skilled, multidisciplinary teams that are able to complete the TEL innovation process. Policy and funding should also support the experimentation that is necessary to generate fresh insights and achievable visions of educational developments.

courses through online learning to people who are unable to study at a conventional university).

We need new ways of judging whether an innovation is successful in enhancing learning. Traditional scientific methods developed for the laboratory, such as randomised controlled trials, have an important role to play in revealing the changes produced by altering individual variables, but are not adequate to deal with situations in which everything has changed because a process of bricolage has engaged the entire TEL Complex. Quantitative measures can signal whether learners know more things, but are less useful in assessing whether their understanding has been deepened or whether they have acquired the skills to learn more or

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## Methods of evaluation are required that can be applied to processes of innovation and to institutional change.

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### Key insight 4: Evidence

Development and implementation of new approaches to teaching and learning must be trialed and tested so that widespread adoption of TEL innovation is based on evidence and not on theory alone. This evidence could come from comparative trials in classrooms or in training environments, judging success by improvement in test scores. It could come from newly emerging sources, such as the learning analytics and comparative (A/B) testing that are enabled by the increasing amounts of data generated by virtual learning environments, MOOCs and other educational technologies. Or it could arise from educational transformations, opportunities to teach or learn in ways that are simply not possible without technology (such as distance education providers offering degree

to work independently in the future. Without valid methods of identifying success, evidence-based innovation cannot take place.

**Summary:** Successful implementation of TEL innovation requires evidence that the projected educational goal has been achieved. Reliable evaluations must be carried out; their findings must be disseminated and acted on. Methods of evaluation are required that can be applied to processes of innovation and to institutional change, as well as those that can be applied to shifts in technology usage.

**Recommendations:** Policy and funding should require the evaluation of TEL innovations in terms of their educational impact. The findings of these evaluations should be available to other researchers and developers,



including those without access to university libraries. New methods of evaluation, such as the use of learning analytics or comparative A/B testing where appropriate, should be developed and put into practice.

The key insights of this report indicate that changes are necessary to the ways in which TEL innovation is planned for, funded and implemented. The continuing need is not for abstract grand challenges or short-term initiatives, but for a sustained building of capacity in technology-enhanced learning, through graduate programmes and investment in national hubs of expertise that share talent and facilities.

### Organisation of the report

The key insights and recommendations set out in this Executive Summary are developed in more detail in the main body of the report. This is structured as follows.

Following the Executive Summary and Introduction:

**Section 2** describes the study on which this report is based. In the first phase, close to 100 projects, products and programmes were considered. Desk research, case study and interviews were used to examine a selection of these in depth. In the second research phase, project team members, with a range of expertise in different fields, worked together to analyse the data, develop insights and write the report.

**Section 3** defines technology-enhanced learning, tracing its origins, identifying its main areas of focus, linking it to related fields and identifying key past policy initiatives. The section goes on to explore different conceptions of education, introducing the idea that education is a super-stable system within

which successful innovation requires attention to a range of different pressures and practices.

**Section 4** provides an overview of TEL successes, pointing to the UK's role as a world leader in this area and identifying TEL's role in developments as diverse as the World Wide Web and the iPad. Three areas of success – the field of mobile learning, the development of the Scratch educational programming language, and the xDelia project that developed learning applications for financial traders – are considered in detail. The section also identifies reasons why TEL successes may go unnoticed, including the significant timescales involved.

**Section 7** examines the implications of this report for research. Persistent intent, engagement over time and the use of an appropriate methodology are identified as priorities. Successful research also requires engaging with the practices and stakeholders that must be taken into account if research-informed innovation is to be embedded in practice. The section ends by considering the implications for researchers of the recommendations identified in this Executive Summary.

**Section 8** examines the implications of this report for policy and for funding, identifying current problems, particularly in relation to sustainability, and proposing

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## The continuing need is not for abstract grand challenges or short-term initiatives, but for a sustained building of capacity in technology-enhanced learning.

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Section 5 deals with challenges to TEL research and innovation. Six misconceptions about these are examined, and recommendations that will increase the potential of TEL to achieve widespread impact are identified. These show that funders, researchers and policy makers all have a role to play in achieving that impact.

**Section 6** sets out key contributions of this report. TEL should be considered as a technology complex, made up of a series of interconnected elements that cannot be changed in isolation. A model of the TEL Complex is set out, centred on a vision of educational change. The TEL Innovation Process is also modelled, and bricolage is set at its heart. Design-based research is identified as a core methodology to support evidence-driven innovation.

solutions. The section ends by considering the implications for funders and for policy makers of the recommendations identified in this Executive Summary.

**Section 9** focuses on the way forward for TEL research. It identifies a continuing need for sustained building of capacity in TEL, through graduate programmes and investment in national hubs of expertise that share talent and facilities.

Boxed case studies provide examples of TEL innovation in practice. ●

# 1 INTRODUCTION

In 2007, the Economic and Social Research Council and the Engineering and Physical Sciences Research Council jointly funded a national Technology Enhanced Learning (TEL) Research Programme.

That programme supported eight large interdisciplinary projects to demonstrate how learning can be transformed through innovative use of digital technology, ranging from developing the social skills of autistic children to training dentists through haptic (sense-of-touch) simulators. Three of these projects have received further funding to embed the findings and technology into educational practice.

As a final initiative of the TEL Research Programme, this report was commissioned to explore the broader issues of translating innovation from early prototypes to sustained impact. Such impact may come through widespread adoption of new technology-enabled methods within the education sector, through successful educational products, or through new activities in homes, museums and outdoor environments that involve learning with technology. The remit of the report is to indicate the barriers to impact of innovations in technology-enhanced learning and to propose new routes to achieving large-scale sustained transformations in teaching, learning and assessment that benefit society.

The report addresses the question:

What should researchers, funders and policy makers do to improve the translation from innovative prototypes to effective and sustainable products and practices?

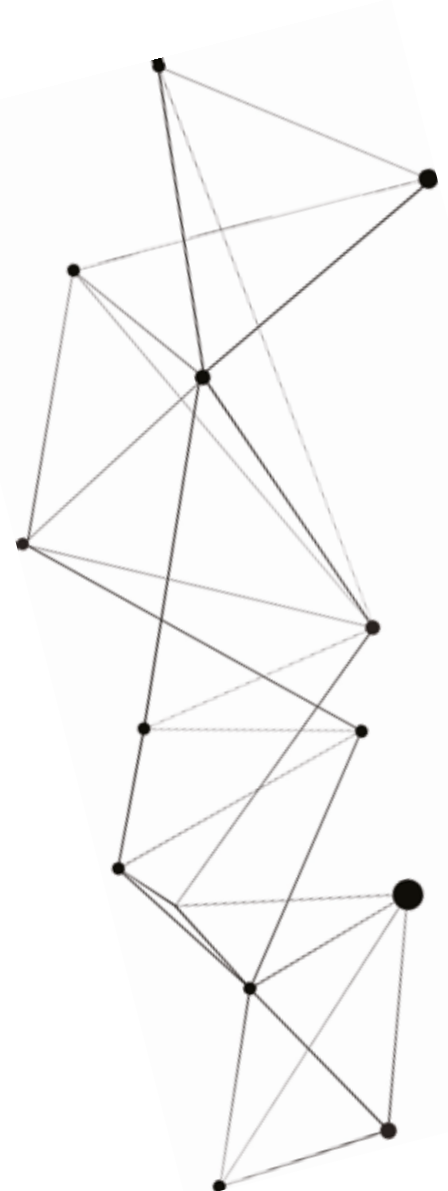
In order to provide answers, the study on which this report is based considered six facets of the general theme of moving beyond prototypes. These can be summarised as: (1) Challenges of commercialisation

within UK and international contexts, (2) Perspectives from different sectors, (3) Audit of UK examples commercialised internationally, (4) Assistance to market, (5) Examples of success and (6) Relationship between impact and commercial exploitation.

One puzzle to be explored is that successive decades have seen major innovations in TEL that have promised to transform education. These innovations have included educational television in the 1960s, language labs in the 1970s, computer-based instruction in the 1980s, integrated learning systems in the 1990s, virtual worlds for learning in the 2000s, and Massive Open Online Courses (MOOCs) in the 2010s. Some of these have received extensive pre-coverage. Yet for none of these has the initial roll out been underpinned by extensive research, nor have any been subject to systematic trials of the kind that might be carried out before the introduction of a new drug into medical practice.

Most of these innovations have faded from national attention. Some, such as language labs and virtual worlds, have been adopted on a small scale within formal educational settings. MOOCs are still in the headlines; few are underpinned by research, and providers are currently looking for ways of assessing the educational impact of various formats. Meanwhile, schools, universities, businesses and individual learners have gradually adopted digital technologies for a wide range of educational purposes, ranging from note taking to online assessment. TEL researchers are often left playing catch-up, assessing the effectiveness of technologies that have already been rolled out at scale.

In order to address this problem, this report examines effective ways of establishing connections between research and successful adoption of TEL. It proposes a model of TEL that extends beyond an initial period of research and development and it connects this model to a process of TEL innovation (see Section 6). ●



## 2 METHODS

Section 2 describes the study on which this report is based. Close to 100 projects, products and programmes were considered. Desk research, case studies and interviews were used to examine a selection of these in depth. Project team members, with a range of expertise in different fields, worked together to analyse the data, develop insights and write the report.

The findings reported here are based on a systematic analysis of data collected from in-depth interviews with key opinion leaders, plus selected exemplar cases, published reports and commentary. To this process was brought the substantial personal expertise of individual members of the project team. The team included experts with extensive experience in pedagogy and technology gained both inside and outside the university sector. These included professors of organisational behaviour and innovation dynamics as well as professors of open education and educational technology. This combination meant that the analysis could draw on and combine insights from these different fields. The report is therefore not narrowly focused on educational technology, but places this in the wider context of understandings of the different types of innovation that are employed in market-oriented organisations.

An additional strength of this study has been the sustained involvement of project team experts at all stages, from research design to data analysis. This has made it possible to review the data critically through multiple interpretative lenses and to adopt a constructivist grounded theory approach [1] to identifying and understanding emergent themes.

The first phase of the research determined an initial list of interviewees and cases, and defined research criteria for the interview and case exemplars. Of particular interest were the impacts, success factors and issues encountered in implementing TEL innovation; the degree to which

each innovation was considered disruptive or in accord with current educational practice; and possible actions to improve impact of TEL research and development.

During the course of the study, close to 100 projects, products and programmes in the area of TEL were identified. The project experts assessed each of these potential case studies in terms of how well it aligned with the six facets of the project. They were also assessed in terms of the required level, nature and ease of access to relevant data. A full list of cases considered in the selection and research process is available on the project website (see Project website box). Approximately half the identified cases were selected for further consideration by initial desk research and, in the light of this work, eight were selected for focused case study. This approach created a tapestry of data, at varying levels of granularity, relating to a wide selection of UK and international TEL initiatives.

A series of interviews complemented the desk research. These helped to identify and explore issues in a more nuanced way than would otherwise have been possible, and provided insight from a range of senior perspectives. Interviewees included international applied researchers as well as directors or senior managers of research institutes, public organisations and private companies. In all, 14 semi-structured interviews were carried out, each based on a protocol developed jointly by the project team. Interviewees' consent was obtained to record and

use their data in the research and, where possible, interviewees were provided with a sample list of questions prior to interview. The project website gives details of the interviewees and of the protocol used. Interviews were recorded and transcribed, and the interviewer checked these transcriptions. In addition, previously published presentations, commentaries and media interviews were used to provide contextual information.

The second phase of the study involved an iterative weekly cycle of data collection and analysis that spanned a two-month period. This allowed theoretical sampling to be used to augment the list of cases and interviewees as themes began to emerge. Each week, every member of the project team was required to code and identify key themes within a selection of in-depth interview transcripts and data from case research [2, 3]. After the weekly coding had taken place, the team met to compare the coded data, agree on emerging themes, and compare their analysis with that of previous weeks. This process provided scope for the expert team members to analyse the data from the perspective of their field of expertise. Emerging themes were recorded as memos on the raw interview transcripts and case study documentation, as well as in the minutes of weekly meetings, and in post-analysis interviews conducted with each team member. In addition, narrative thematic analysis [4] was undertaken on a selection of TEL research linked to the UK Teaching and Learning Research Programme that gave rise to this report. Where possible, project impact reports were examined, in order to explore the measures of impact reported by each project.

During analysis, it was found that publicly available documentation

## Project website

Full details of the Beyond Prototypes study are available on the project website <http://beyondprototypes.com/>, including the methodologies for data collection and analysis, an overview of case studies considered, and some in-depth case studies

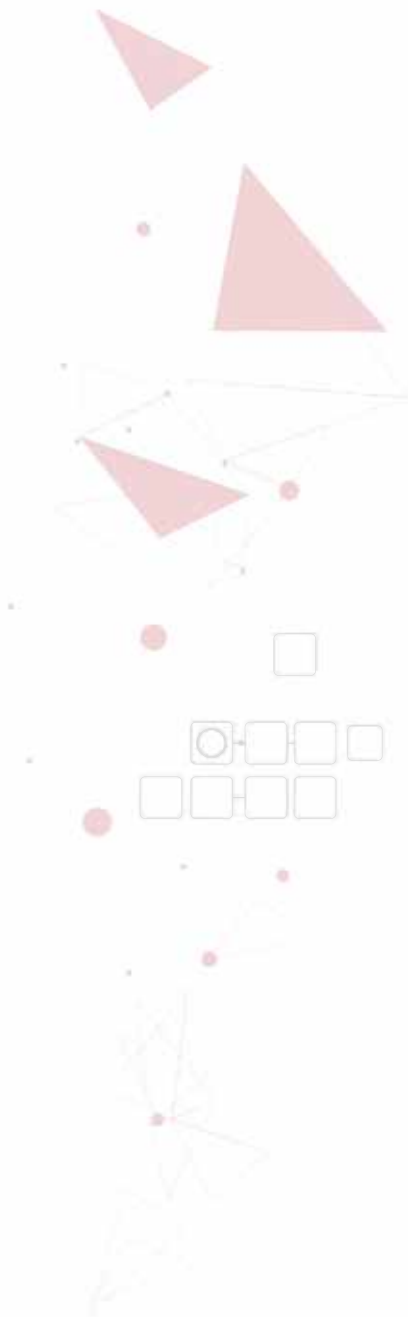
often lacked sufficient information about non-academic project implementation and about the impact and exploitation of the work during the lifetime of the project and after its formal conclusion. In some cases, it was difficult to find links to final or impact reports produced by funded projects. Desk research therefore highlighted the need for more information about the actual, and often challenging, practice and experience of implementing research and achieving impact. It also drew attention to the lack of clarity demonstrated by many projects about plans for exploitation and, specifically, the reasoning and evidence for claims such as expecting ‘large-scale use of project results’. This initial finding has been taken into account in this report’s recommendations related to evidence.

The theory development phase of the analysis initially focused on creating a broad reporting narrative through which to present the themes identified. It then went on to develop a model for the innovation process. As with earlier phases, existing theory and concepts were considered together with the themes emerging from the research. The breadth of the study’s scope meant that theoretical saturation was not expected across categories. Nevertheless, a high degree of confluence was observed across interviews, indicating that appropriate emergent themes had been identified. These themes, which are explored in Section 6, were the TEL Complex, persistent intent, bricolage and evidence. ●



### 3 WHAT IS TEL?

Section 3 defines technology-enhanced learning, tracing its origins, identifying its main areas of focus, linking it to related fields and identifying key past policy initiatives. The section goes on to explore different conceptions of education, introducing the idea that education is a super-stable system in which successful innovation requires attention to a range of different pressures and practices.



Technology-enhanced learning (TEL) research focuses on how technologies can add value to learning and teaching processes. Today's learners have access to increasingly powerful and affordable handheld computing devices, including smartphones, games consoles and tablet computers. They can share, interact and immerse themselves online with others through the use of social networks and virtual worlds. They can also create identities and user-generated resources that potentially have a virtual worldwide audience enabled by the Internet. Learners' activities can be captured in real time and feedback processes automated with increasing precision through learning analytics. Technologies that allow users to post material and messages online have the potential to support learner inquiry, to offer new modes of representation and expression requiring new forms of literacy, to support innovative thinking and problem solving through collaboration, and to allow publication of work to an authentic external audience [5].

TEL is able to make use of different forms and formats of technology in the pursuit of more engaging and beneficial forms of teaching, learning, pedagogy and assessment. As this report highlights, good pedagogic intentions lie behind some of this development but, 'many important TEL developments have often come from innovating with technologies developed for other purposes' [6].

Technology-enhanced learning has emerged as a preferred term of

reference for the research community working in this area. The term is more generous and encompassing of new practices than the wide range of related labels, including 'educational technology', 'computer-aided learning', 'Information and Communication Technologies' (or 'ICT', as they are often referred to in the schools sector), and 'e-learning', to name but a few. 'Technology-enhanced learning' stresses that the technology is employed in service of the learning, and that it is not just adopted, but is expected to deliver improvement.

References to TEL, in relation to support and training, began to emerge in the 1990s and the first TEL conference appears to have taken place at the end of that decade. TEL-isphere 1999, held in Barbados, focused 'on the use of communications and information technologies, and their potential to enhance learning experiences through helping students become active participants in the educational process' [7].

Even before the emergence of TEL as a named field of research, UK government policy was driving innovation in this area. The *Beyond Prototypes* website includes an overview of relevant policies in the UK over the past decades, and a selection of those from Scotland, which has developed distinctive policies of its own. The website also contains a detailed version of the boxed case study included here, which deals with the implementation of the Microelectronics Education Project, providing an early example

of government policy driving a well-structured process of TEL innovation.

In 2001, the final report of the European Commission's Open Consultation Process on 'New Research Challenges for Technology Supported Learning' clearly set out a series of recommendations designed to further the research agenda for technology-enhanced learning. These were to be carried out as part of the Sixth Framework Programme (FP6) [10]. The report offered a response to the fragmented nature of intellectual, disciplinary and research community agendas related to technology and education at the time [11]. A diversity of TEL research effort had resulted from the different cultures, traditions and trajectories associated with the various national educational systems, and their highly differentiated experience of and ambitions for using technology in support of learning.

Successive programmes funded by the European Union (EU) have served to aid the integration of research and the emergence of new research and doctoral communities in relation to technology-enhanced learning. These have included the PROLEARN Network of Excellence that dealt with technology-enhanced professional learning (2004-2008) and the Kaleidoscope Network of Excellence focused on technology-enhanced learning and access to cultural heritage (2004-2008). These were followed by STELLAR, the European Network of Excellence in TEL (2009-2012). The STELLAR website specified that the network represented 'the effort of the leading institutions and projects in European Technology-Enhanced Learning (TEL) to unify our diverse community'. Each of these networks brought together broad teams of researchers working in diverse fields, including computer-supported collaborative learning (CSCL), blended and informal learning,

as well as authoring systems and immersive environments.

STELLAR played an important role in unifying research agendas and setting mid-term challenges for the research community, while recognising the complexity within and between the educational systems of partner countries [12]. TEL research communities now seek to adopt more collaborative and inherently interdisciplinary approaches that bring together educational, learning and computer sciences, as well as related disciplines.

Despite these moves towards unity, there still exist many closely related and overlapping research areas that would not describe themselves as primarily TEL communities. These include, for example, those focused on educational data mining, artificial intelligence in education, networked learning and learning analytics, as well as those identified in the paragraph above.

Within the UK, the work of the ESRC Technology Enhanced Learning Research Programme echoed that of the European Commission by

## Case study: Microelectronics Education Programme


The £23 million Microelectronics Education Programme (MEP) for England, Wales and Northern Ireland was established by the Government in November 1980 and ran for six years. The aim was to support schools in preparing children 'for life in a society in which devices and systems based on microelectronics are commonplace and pervasive'. To complement this work, the Department of Industry made £16 million available to help local education authorities purchase computers for schools.

MEP took into account areas as diverse as curriculum development, teacher training, resource organisation and support. It promoted change at national, regional and local levels, encouraging collaboration and cross-fertilisation of ideas. Plans for evaluation and field studies were incorporated from the start. Although there was relatively little emphasis on pedagogy, the programme did note the potential to 'add new and rewarding dimensions to the relationship between teacher and class or teacher and pupil' [8].

A report by Her Majesty's Inspectorate in 1987 found that, while the MEP was only one of the agents of change and innovation in the field, 'work with IT in schools and associated staff development owed much directly, and even more indirectly, to the programme.' It noted the challenges associated with attributing direct impact to the programme because there was much activity in schools around microelectronics at the time and MEP resources were often channeled indirectly to schools. However, the report found that the strategy adopted by MEP considerably strengthened the number of well-informed teachers and trainers, that those involved often showed a resilience that allowed them to overcome difficulties and uncertainties which was necessary for successful implementation, that an impressive range of materials was developed, that closer links were formed between training and curriculum development in IT, and that the cascade principle of teacher training worked well where opportunities were offered [9].



## Arenas for informal learning, non-formal learning, lifelong and professional learning are very much part of the TEL research agenda.



promoting unity within the research field. The initiative represented a substantial programme of work that was funded equally by two of the UK's Research Councils, the ESRC and the EPSRC, from 2007 to 2012. The core aims of the TEL Research Programme were to design and evaluate systems that would advance understanding of learning and teaching in a technological context, and that would also improve teaching and learning practice.

In some ways, the TEL label can place a bind on researchers. From the perspective of practitioners and policy makers, 'technology-enhanced learning' captures the need to realise more from the potential of technology to assist learning processes. However, the term can also obscure the need for teacher support and development that is often required to ensure positive impact in the classroom or other educational context.

TEL is not limited to technology-enhanced education; the world of learning goes on outside the formal learning settings of the classroom and the lecture hall. Lifelong learners also engage in non-formal learning, including vocational and workplace training, which is not accredited by a traditional academic institution. At other times, they will be involved in informal learning, in settings where they choose their own methods, define their own goals, or work towards shifting goals [13]. As the case studies in this report demonstrate, arenas for informal learning, non-formal learning, lifelong

and professional learning are very much part of the TEL research agenda. This engagement with different forms of learning adds layers of complexity to an already busy research arena.

While members of the TEL research community have sought to define and reach agreement on the key questions and the 'Grand Challenges' that can drive innovation in educational and learning systems, it is worth considering the nature of the challenge faced by TEL. Everyone has experienced education and will have a view about the role of technology in supporting that experience.

While there may be openness to the integration of technology into other aspects of everyday life, there is a variable but understandable resistance to innovations that tamper with the dominant educational or training practices, unless a particular innovation is occupying a new niche.

### 3.1 Understanding education

In reflecting upon the general theme of moving beyond prototypes, it is important to understand different ways in which the role of education may be characterised.

**Education as a service:** In some instances, education has been considered as a service, in the sense that learning resources are provided for learners and teachers. The BBC Bitesize and OpenLearn websites are among the current examples of good quality educational resources available online, many of which are available free of charge. Due to the wealth of resources available, learners and teachers need to be strategic in determining which resources to access and how to use them to build on current understandings. Understanding education as a service prompts a focus on innovation relating to brand (the distinctive sets of values

associated with an organisation), channel (the means for delivering resources to learners and teachers), product system (the overall bundle of services) and service (interactions providing value for users) [14]. These product-focused types of innovation can influence how efficiently teaching is delivered, and the quality of the resources available to learners, but they are concerned with only limited areas of teaching and learning and do not require an improved pedagogic approach.

**Education as media production and presentation:** Some Massive Open Online Courses (MOOCs) present education as a process of media production and presentation. These courses, sometimes referred to as ‘xMOOCs’ or ‘behaviourist MOOCs’, are distinctive in that they are focused on interaction with content. They have a traditional linear structure, with targeted activities punctuating the acquisition of new knowledge [15]. High enrolment rates on these courses show that this approach can be very successful in attracting potential learners but, at the same time, high drop-out rates point to the disadvantages of treating education simply as a process of production and presentation. Such MOOCs may adopt an innovative profit model, an innovative structure, an innovative process or an innovative channel for course delivery [14]. Once again, although innovation in these settings may be significant, it does not require an improved pedagogic approach or imply an increase in educational impact on individual learners.

**Education as a conversation:** Theorists from Dewey to Laurillard see education as a conversation during which we adjust to each other’s perspectives [16, 17]. Learning is a process of coming to know through meaning making and conversation. Online tools allow extensive and extended

conversations about learning to take place both asynchronously and synchronously, but concerns about focus, privacy and e-safety, as well as the logistics involved in providing the necessary technological infrastructure and support, all work against adoption of the use of these tools in the classroom. This understanding of education opens the way to significant TEL innovation, focused on changes in practice and pedagogy that, enabled by the use of technology, can produce measurable educational impact.

The three paragraphs above set out different ways in which education can be understood. The first two focus on resources and delivery and are associated with processes of innovation and development that are already well understood [14]. The third, education as a conversation, is the one that is most reliant on the process of TEL innovation rather than on innovation in areas familiar from business, such as brand and profit model. In order to engage successfully in TEL innovation, it is important to look at education not only as a process but also as a system.



You look at the [US] educational establishment, and if there’s any change it’s very slow. I don’t think the educational establishment has really embraced these ideas. And, to the extent they embrace them, I think a lot of times it’s surface rhetoric and the reality underneath hasn’t changed. Business leaders will say, ‘We need a different type of workforce in the future. We need different types of learners. We need people who are creative and collaborative.’ But then you see what they oftentimes recommend for the schools, as just a small incremental change from the way school has always been. So the rhetoric of what people say is needed doesn’t get matched with what they really call for in schools. //

**Mitch Resnick**

Head of the Lifelong Kindergarten group at the MIT Media Lab

### 3.2 Education as a super-stable system

A system typically combines a set of interdependent components. In the educational system, innovators who are aiming for educational impact not only have to consider aspects of teaching and learning, but also how the change will interact with other aspects of the system’s operation.

Unless an innovation is well aligned with the system into which it is introduced, the chances are that it will be resisted or ignored by the system. Unless the necessary development and support systems are available, teachers will rarely have the time or the inclination to test and adopt new practices. This means that education is a super-stable system, and the classroom is a challenging space within which to innovate. In order to understand these challenges, which are inherent in the TEL innovation process, it is necessary to understand why education, as a super-stable system, is resistant to change.

An important theme in organisation theory research concerns explanations of stability and homogeneity in organisational



configurations and practices. A strong and overlapping set of explanations come from open systems theory [18] and from institutional theory [19]. Both emphasise the role of multiple overlapping and mutually reinforcing systemic pressures in maintaining stability in organisational practices. These pressures also play a role in bringing about homogeneity between practices in organisations facing similar environment pressures.

Institutional theory emphasises the role of three forms of pressure in determining and legitimating particular practices. These pressures are coercive (laws and regulation), normative (social values and expectations), and cultural-cognitive mindset (culturally determined and reinforced understandings of the world). Where organisational practices are strongly institutionalised, in that they are underpinned by such multiple reinforcing sets of determinants, they can be very hard to disturb. For example, research shows that management innovations in a parent company may be hard to transmit to subsidiaries in a different country where practices are underpinned by different institutional pressures [20, 21].

Other research suggests that changing a single system within an organisation often fails to produce intended changes without changes to associated systems. For example, a large study of middle managers in private sector firms showed training in new management approaches to be ineffective in bringing about desired change without attention to the role of pay systems, promotion systems, allocation of resources and symbolic communication from senior managers in reinforcing existing behaviours [22].

Education systems are, in the sense above, strongly institutionalised. Educational practices are

underpinned and reinforced by multiple overlapping social forces and intertwined with other mutually reinforcing practices. Coercive pressures include not only central government legislation and regulation but also national examination systems and the bodies that control these. Normative pressures include public and political expectations that are mediated and amplified by the media, the role of professional bodies and employer organisations; cultural cognitive mindsets are reinforced and transmitted by the strong role of apprenticeship in teacher development.

Within education systems, different practices play a mutually reinforcing

what is needed [...] and we're taking the school in that direction. Policy comes at us and we'll sort of harness it to continue going in that direction' [23, p.51].

Accounts of successful change within such institutionalised systems emphasise the importance of bridging and brokering across organisational boundaries and understanding that practices have to be recreated in new contexts to function within the ecology of practices into which they are being introduced [21, 24, 25]. Section 4 provides an overview of some of the significant successes achieved by TEL, demonstrating some of the ways in which boundary crossing takes place. ●

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## Changing a single system within an organisation often fails to produce intended changes without changes to associated systems.

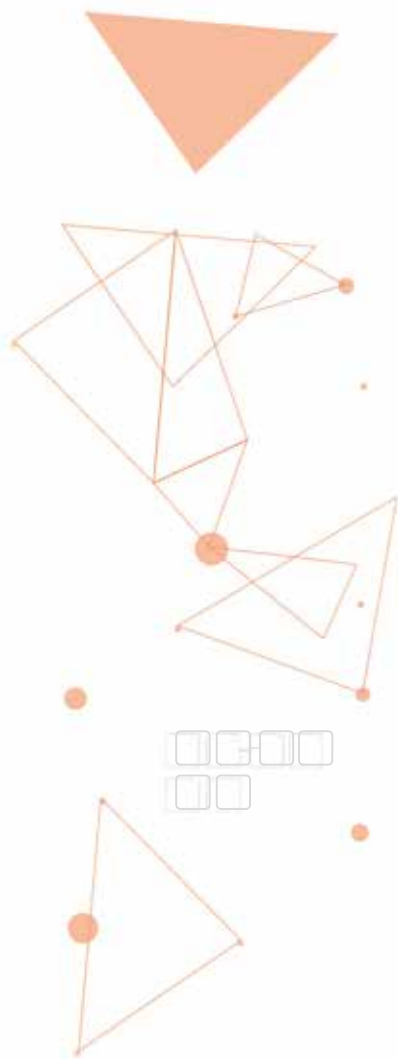
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role. Pedagogic practices interact with and are constrained by timetabling practices, budgeting practices, safeguarding practices, inspection practices, data capture practices, governance practices, assessment practices and many others. Initiatives that seek to change just one practice component are unlikely to achieve traction unless attention is paid to other elements of the system.

Ball and colleagues [23] documented the difficulties of policy implementation in schools. Their findings mirror some of the conclusions presented in this report. They found that policies are translated, interpreted and absorbed into existing ways of doing things, often being markedly changed or de-natured in the process. As one of the deputy heads they interviewed stated, 'I think we know what we want to do with our school, we know exactly

## 4 ACHIEVEMENTS UNDERPINNED BY TEL

Section 4 provides an overview of TEL successes, pointing to the UK's role as a world leader in this area and identifying TEL's role in developments as diverse as World Wide Web and the iPad. Three areas of success – the field of mobile learning, the development of the Scratch educational programming language, and the xDelia project that developed learning applications for financial traders – are considered in detail. The section also identifies reasons why TEL successes may go unnoticed, including the significant timescales involved.



The UK is currently a world leader in the area of TEL. BETT – formerly known as the British Educational Training and Technology Show – has been running since 1985 and is the largest educational technology event in the world, bringing together over 35,000 educators and learning professionals. A recent list of the top 20 e-learning companies in Europe in terms of their innovation, scale, market impact and revenue growth included 10 UK firms [26].

Successful TEL interventions have been identified and catalogued in different reports [6, 27]. In *System Upgrade: Realising the Vision for UK Education*, Noss highlighted one recent set of examples:

***The Technology Enhanced Learning research programme has spent more than four years developing systems and software that, for example, use artificial intelligence to teach teenagers algebra and help autistic children with their social skills. We have created virtual islands where young people acquire the confidence to tackle some of life's bigger challenges. We have exploited the potential of giant touch-screen tables to encourage young children to work together. We have taken sense-of-touch technology – the sort that makes that gaming controllers vibrate – and used it to train dentists cheaply and effectively [6]***

International reviews suggest that TEL interventions lead to outcomes

that have impact on a similar scale to that produced by other educational interventions [see, for example, 28, 29, 30]. Interventions that have claimed a larger impact, such as Cognitive Tutors (see boxed case study), have taken decades to develop for a limited range of curriculum topics. As Borgman and her colleagues comment,

***New technologies follow complex trajectories often supported or thwarted by other technologies, infrastructural issues, competing standards, social systems, political decisions, and customer demands [31, p17]***

The extended period of development that precedes successful implementation means that the scale of TEL success may go unnoticed by observers who are expecting fast results or by those who are looking for a new product or procedure and thus do not notice the emergence of an entire field, such as mobile learning, from TEL research. It may go unnoticed by observers who expect the results of TEL research to be confined to the field of education and so do not make the connection between TEL innovation and life-changing developments such as the World Wide Web. It may also go unnoticed by those who are expecting a linear model that proceeds from idea to pilot to full-scale roll out. The ecological model of TEL points to the ways that different components combine and intermingle; one vision diffuses and inspires others.

## UK centres of excellence in TEL

UK centres of excellence in TEL research have been prominent in national, European and international networks. The largest assembly of TEL researchers in the UK is at The Open University, with some 30 academics in the Institute of Educational Technology and a similar number of people with a core research interest in TEL spread across the Knowledge Media Institute and university faculties.

The London Knowledge Lab, a partnership between the Institute of Education and Birkbeck, has around 50 academics engaged with research into digital technologies, new media and knowledge. At the University of Nottingham, the Learning Sciences Research Institute is a centre of excellence for research in the learning sciences and technological innovation, engaging 12 core academics. These three institutes have formed CTCL – a collaboration aimed at sharing research and innovation. This includes running a series of ‘What the research says...’ events for industry, practitioners and policy makers.

Other centres of research excellence include the Centre for Innovation in Technologies and Education at Southampton; the Centre for Learning, Knowing and Interactive Technologies at Bristol; the Serious Games Institute at Coventry; the Learning and New Technologies Research Group at Oxford; the Educational Technology Research Group at Warwick; the Centre for Studies in Advanced Learning Technology at Lancaster; the Children and Technology Lab at Sussex; the Centre for Applied Research in Educational Technologies at Cambridge; the Institute of Learning Innovation at Leicester; the Caledonian Academy research centre at Glasgow Caledonian, and the Technology Enhanced Learning Group at Durham.

A recent national initiative has been the formation of the Future Learning Academic Network. The network brings together academics from Birmingham, Edinburgh, Exeter, Glasgow, Leeds, Loughborough, Nottingham, The Open University, Reading, Sheffield, Southampton, Strathclyde and the University of East Anglia, all of whom are engaged with research related to FutureLearn and innovations in learning with technology.

sometimes prove easier to market outside formal education. This has been true of Alan Kay, whose work on the handheld Dynabook learning device in the 1970s led to the development of the iPad [34]; Nicholas Negroponte, whose One Laptop Per Child project also developed technology for wider consumer use [35]; Seymour Papert, whose work on constructionist learning led to collaboration with LEGO in creating the Mindstorms robot-building kits and to millions of children worldwide learning to program computers [36]; and Tim Berners Lee, whose work on managing knowledge led directly to the creation of the World Wide Web [37].

The Web began as a project to provide physicists at CERN with facilities that could support learning by information sharing and data exchange. These physicists formed a widely dispersed and computer-literate group, using different computers. Tim Berners Lee wrote a simple hypertext program called Enquire to keep track of people and programs; enabling mail and file interchange between different types of computer system and different networks. Developing the Enquire code led him to something much larger, ‘a vision encompassing the decentralized, organic growth of ideas, technology and society’ [37:1]. This was not a smooth progression.

*The Web arose as the answer to an open challenge, through the swirling together of influences, ideas, and realizations from many sides, until, by the wondrous offices of the human mind, a new concept jelled. It was a process of accretion, not the linear solving of one well-defined problem after another. [37:3]*

TEL research has led to the development of major innovations that have taken root across the world.

Educational technology has been the inspiration or catalyst for many other activities. TEL is an endeavour that attracts people from many different fields. The theme of ‘enhancing education through technology’ has captured the imagination and efforts of innovators in computing, technology and psychology. This can be seen as far back at the 1950s, when Skinner introduced the concept of ‘teaching machines’ [32], and the 1960s, when Engelbart developed

a conceptual framework for augmenting the human intellect [33].

Researchers working to develop technologies for educational enhancement have generally found that creating successful educational technology is harder than they had anticipated, that it takes longer than they had planned, and that the route from vision to implementation is more circuitous than they had expected. The products of their innovation

It has also had important successes both within and beyond the field of education, ranging from broad areas of development to more focused achievements. The following sections consider three very different examples of TEL success. In each case, innovation is an extended process, in which an understanding of the ecologies and communities within which innovation will be embedded is developed over time. Although these innovations require the use of technologies, they are not dependent upon a single technology, the equipment that is employed changes over time. This is particularly clear with the first example, mobile learning.

#### 4.1 Success story: mobile learning

The development of mobile learning can be traced back to its origins in TEL research.

*In the earlier half of the last decade, sophisticated mobile technology was scarce, fragile, expensive and difficult, and was the prerogative of institutions. In the second half of the decade, mobile technology became universal, robust, cheap, diverse and easy. [38]*

Researchers began to study the potential of mobile devices to enhance fieldwork, allowing students to learn when and where they needed to do so [39]. The findings of small-scale studies led to a vision of mobile devices able to support lifelong learning, devices that would be portable, available anywhere, adaptable and intuitive to use [40]. Since then, mobile phones have become smart phones, and generations of personal digital assistants (PDAs) and other mobile technologies have come and gone but researchers have continued to work towards that vision of educational innovation.

In the early 21st century, with cheap and robust mobile technologies widely available, the European Union began to fund major multinational partnership projects, including MOBIlearn and M-learning. This supported the development of mobile learning from a small-scale research interest to an international phenomenon [41]. More than 26 million people in Bangladesh have now accessed the BBC Janala language learning service on mobile phones [42]. Alongside developments in Europe and Asia, the USA has also awoken to the possibilities of mobile learning, and the spread of mobile devices.

Based on his experience of mobile learning projects, Steve Vosloo, senior project officer in mobile learning at UNESCO, highlights the challenge of assessing the new skills that young people are learning through TEL:

*There aren't really recognized measures for these. What you find doesn't fit neatly into the standard assessment system. So actually conducting the assessment, when the standard formal assessment does not necessarily recognise all of the learning that's taking place, was definitely a challenge. That's probably something that comes up in TEL quite a lot. [Steve Vosloo]*

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### There are schools that buy the latest tablet computer or handheld gadget and only then consider how to use it.

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Following mobile technology research in education at the beginning of the century, such as the Palm Pioneers project [43], there has been a stream of innovation in the US around 1:1 learning with handheld devices in classrooms and lecture theatres.

Sheer weight of numbers provides some indication of the success of these innovations, but it is difficult to use scientific methods developed for laboratory use to assess a shift in learning behaviour on this scale. It is clear that people are benefiting from opportunities to learn in contexts that were never possible in the past, but there is still much work to be done to enable consistent educational impact. While some schools have adopted innovative approaches to developing mobile learning between home and school: there are schools that buy the latest tablet computer or handheld gadget and only then consider how to use it.

Providing evidence-based research that can support learners and teachers to make informed decisions about engagement with mobile learning is a continuing challenge.

#### 4.2 Success story: Scratch

A different form of TEL success is represented by Scratch. This is a visual programming environment for children to create and share interactive stories, games and animations and to think creatively, reason systematically, and work collaboratively [44]. Scratch is a project of the Lifelong Kindergarten Group at the MIT Media Lab, headed by Mitch Resnick, and has received funding from the US government National Science Foundation, private companies and foundations. First launched in 2007, and provided free of charge, approximately 4 million Scratch projects have already been uploaded and shared by users. A spin-off online community for educators called ScratchEd was launched in July

2009, highlighting the value of the programming environment for formal as well as informal learning.

The project had its origins in more than 40 years of development at MIT of research on children learning through programming. This was strongly influenced by Seymour Papert's work from the late 1960s onwards, including teaching children to control a programmable 'turtle' using the Logo programming language [45, 46]. Papert's research, in turn, drew on the work published by developmental psychologist Jean Piaget from the 1930s to the 1970s.

*In working with Seymour Papert and being involved with the Logo community, I saw a lot of what drove it and what limited it. I saw both the strengths and the weaknesses of the Logo Community. We went on to start our own network of after-school centres, the Computer ClubHouses. The initial inspiration for Scratch came from our work at ClubHouses, where we saw what kids were looking for and realised that there were no good tools available. [Mitch Resnick]*

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**The initial inspiration for Scratch came from our work at ClubHouses, where we saw what kids were looking for and realised that there were no good tools available.**

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Scratch emerged not only as a consequence of researchers' educational vision and experience but also as a consequence of the sustained engagement the team had with young learners through the ClubHouses. The first, and flagship, Intel Computer ClubHouse in the Network was opened in collaboration with the MIT Media Lab in 1993 at the Computer Museum and later moved

to the Museum of Science, Boston. Sponsors have since included Adobe, Autodesk, Hewlett-Packard and LEGO systems and today there are over 200 ClubHouses around the world.

This long history of development and of community building over a period of more than 40 years, provided the inspiration and basis for the development of Scratch. The influence of this work is still increasing and is becoming increasingly evident in Europe. In the UK, government policy now places increased emphasis on programming within the curriculum. This is linked with a growth in after-school programming clubs and in teacher training. The organisation Code Club, for example, has over 1200 clubs nationwide. Both in school and out of school, Scratch is used as a gateway to programming. Elsewhere in Europe, there is similar interest in programming and computing environments. For example, the Portuguese government has developed a partnership between the government, a higher education institution, and internet provider SAPO that seeks to provide continuing professional development and that has a focus on Scratch.

In 2013, the first European Scratch conference was held in Spain and 'Scratch Day' was marked by 184 events in 47 countries.

Scratch is an example of an innovation that has succeeded by running alongside the education system in its use in informal settings outside the classroom and in the development of a network for sharing the creative

products produced by children. Its innovative features come from the configuration of software and social networking elements. Like much TEL innovation, it has involved the assembly of existing skills, ideas and resources in a new and productive way. It has also involved extensive work in building and engaging with the communities involved.

### 4.3 Success story: xDelia

Extended work with stakeholder communities was key to the success of xDelia ([www.xDelia.org](http://www.xDelia.org)). This was a three-year project that combined research into the decision-making, learning and trading practices of professional and private financial traders with the development of learning applications. The project explored the role of emotions and emotion regulation in financial decision-making and how learning interventions that focused on improved emotion regulation might improve financial decision-making. In its later stages, the project evaluated a series of learning interventions that exploited a combination of physiological sensors and serious games approaches. These interventions were combined in an overall pedagogic approach founded on an understanding of the role of emotions in trading, practice-based approaches to learning and a close understanding of traders' trading and learning practices.

The project was funded by the EU as part of the Seventh Framework Programme (FP7) and was carried out by a consortium of academic institutions and a commercial partner. The initial stage of the project took the form of in-depth studies of the behaviour of traders and the ways in which their emotional state influences their decision making. The project focused on a particular emotion-driven trading bias as a proof of

concept: the tendency to hold loss-making assets longer than assets at a gain (the disposition effect).

Novel use was made of physiological sensors to provide feedback on emotion regulation capabilities, and games were developed that mimic important aspects of trading and financial decision making. The project successfully demonstrated links between engagement in the learning interventions and real-world behaviour; it also built on work demonstrating links between traders' effective emotion regulation and performance. Outputs from this work are being exploited in several different contexts and Saxo Bank's online investor education platform for its clients has developed an approach to developing clients' understanding of the role of emotions in their trading based on outputs from the project.

In comparison with the other examples discussed in this section, xDelia is a good example of a time-bounded project that, in three years, was able to move from initial concept to a fully embedded concept with demonstrable educational impact. This process, though, was based on extended engagement with the communities involved. Jeffrey Lins, head of advanced research and innovation at Saxo Bank, was a project partner. From his perspective, the establishment and success of the consortium were rooted in earlier work

***The academic lead on xDelia has a remarkable understanding about how it works inside investment banks, not only because he's studied it academically but, having interacted with these kind of organisations, he understands them [Jeffrey Lins]***

He also attributed the success of the project to exploratory studies and to reviews of previous work

that were carried out at the start. These provided the consortium with a detailed understanding of the environments in which their work would be implemented.

in TEL, sensors, the psychology of decision-making and emotion regulation, behavioural economics, neuroeconomics, and financial trading and markets.

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## xDelia was able to move from initial concept to a fully embedded concept with demonstrable educational impact.

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The work also extends forward, beyond the period of project funding. Early work has now begun, in collaboration with commercial organisations, to explore the potential of the approaches developed by xDelia in other fast-paced environments such as training racing car drivers and air traffic control. A vision of using learning interventions to improve emotion regulation in high-pressure situations links this work over time. As with the other examples in this section, the core of the work is not a single technology, but a willingness to make use of technology to achieve a vision of enhancing learning.

xDelia can therefore be understood as one element of a large body of work that extends over time. However, it was also successful in delivering a significant innovation in a relatively short time frame. Key features of the project enabled this success.

- Research team members had a close understanding of the ecology of practices in the areas where the innovation would be embedded
- There was close collaboration with a commercial partner from the outset, which played a significant role in the research and development process.
- Exploratory studies investigated the nature of existing informal and formal learning practices in these environments.
- The target audience was involved in early studies and trials.
- It engaged a highly cross-disciplinary team, with expertise

- There was a strong commitment to dissemination by engagement rather than by broadcast.

These features are shared with the other TEL successes considered in this section. A close attention to the innovation process by consortium members, and an understanding of the importance of previous developments and cross-community engagement, enabled the xDelia team to work through the innovation process consciously and relatively quickly. In Section 6, these features are brought together in a model of the TEL Innovation Process. This process also takes into account the misconceptions and challenges that may be encountered by researchers. These are considered in Section 5, together with ways of addressing them. ●



## 5 TEL INNOVATION: CHALLENGES AND MISCONCEPTIONS

Section 5 deals with challenges to TEL research and innovation. Six common misconceptions are examined and recommendations are identified that will increase the potential of TEL to achieve widespread impact. These show that funders, researchers and policy makers all have a role to play in achieving impact.



The TEL research community has had undoubted success in extending the vision and reach of innovations that have reached millions of people worldwide, notably mobile learning [47, 48] and MOOCs [49]. TEL has provided theoretical underpinning for technologies that are used to support learning, and policy briefings advising on how these technologies can be used to achieve educational impact. This work has included critical appraisals of tools that are widely used in schools and universities, including integrated learning systems [50], interactive whiteboards [51] and virtual learning environments [52]. The enduring success of The Open University is closely allied with research into innovations in TEL [53, 54]; this research drives the continued adoption of new methods of distance learning and assessment.

Despite its achievements, the TEL research community has neither the coherence nor the scale of other scientific communities such as particle physicists or climate scientists. For example, the World Climate Research Programme ‘organizes large-scale observational and modelling projects and provides the international forum to align efforts of thousands of climate scientists to provide the best possible climate information’ [55]. By contrast, the STELLAR European Network of Excellence in TEL [11], funded by the European Commission, integrated 15 leading research organisations in TEL between 2009 and 2012. It was successful in coordinating research, informing governments of TEL innovations, and supporting initiatives such as the European Conference in Technology Enhanced Learning, but

it would not claim to have aligned the efforts of thousands of learning scientists.

Grand challenges of TEL such as ‘Make use and sense of data to improve teaching and learning’ [12] have the potential for more immediate social impact than the hunt for the Higgs Boson, but have never captured the public imagination. Why is this? One reason is the complexity of TEL, which will be examined in Section 6. The most straightforward approach to innovation is to focus on marketing a technology, rather than on the complexities involved in using that technology to achieve significant educational impact. However, the technology by itself is not the innovation, the importance of the technology lies in the ways in which it can enhance learning by supporting or transforming a particular pedagogy or practice. Without these underpinning elements, it is likely to be reduced to an expensive way of doing something that was done more cheaply in the past.

To give one example, the original conception of interactive whiteboards as a TEL innovation brought together a complex of technology and practices. These included practices related to pedagogy, classroom organisation, teacher-pupil relationships, staff development and technical support. Changes to all these practices were required in order to realise the boards’ potential for fostering interaction, creativity and collaboration. However, a study of their use in schools noted that ‘the tools of educational technology have no magical power in themselves; only by being embedded

in the practices of teachers and learners do their mediational means come into play' [51].

Without training and technical support, sometimes without reliable network connection, careful set-up, or budget for replacement parts and repairs, it is difficult for teachers to use interactive whiteboards in ways that support learner engagement and interaction. Nevertheless, the boards have often been purchased without attention to these practices. It has proved easier to present the boards purely as an innovative technology that can be bought, installed and used. This approach has reduced opportunities for significant pedagogical impact because it treats the new technology as a direct substitution for the previous blackboard or whiteboard, and pays little or no attention to the support and resources required in order for teachers and learners to gain extra benefits.

In such cases, the failure to achieve educational impact is associated with a failure to recognise that TEL innovation consists of a process of implementation rather than a technology. The sub-sections below set out a series of misconceptions that can limit the success of TEL innovation, and identify ways of addressing these and thus improving the potential of the TEL research community to achieve widespread public or commercial impact.

### 5.1 Shift the focus from technology to pedagogy and practice

**MISCONCEPTION:** The technology is the innovation. Innovation therefore follows a linear path from idea to prototype, deployment and evaluation.

As set out above, the temptation, particularly in time-bounded, grant-funded projects, is to focus on a

technological innovation. A visible technology such as One Laptop Per Child (OLPC) has an obvious appeal for governments and media, but its development has been criticised for divorcing the provision of technology from its content, training and use [56].

**Technology should not be the primary driver of educational activity; it should support it. Technology such as the XO-1 [the computer model developed for the OLPC project] should only ever be considered as supportive of educational practice, never as core to it. [56:244]**

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## Technology should not be the primary driver of educational activity; it should support it.

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Starting with an educational challenge is more likely to produce successful educational transformation than starting with a technology. A review of the use of interactive whiteboards in schools in 2011 concluded that

**there is a need to reassess the use of computer technology from an educational, rather than a technological, perspective; and develop a more sophisticated conceptual model of how ICT can facilitate teaching and learning in the classroom. [51:362]**

While the new 'app economy' that markets software applications could theoretically produce educational software that can be transported into classrooms and shown to improve learning outcomes, this is unlikely given the past failure of individual technological resources or tools to have a major influence on education. We need to look beyond the linear model of TEL innovation, in order to see how new technology-enabled methods of teaching, learning, and

assessment could have a sustained effect on the practice of education. Learning through social networking, the use of mobile devices to support lifelong learning, the use of analytics to improve learning design – all these visions of the enhancement of learning by technology involve the creation and implementation of new systems rather than specific pieces of software.

**RECOMMENDATION:** Policy and funding should support and encourage changes in pedagogy and practice, as well as the technological developments that will support these.

### 5.2 Look beyond the formal education sector

**MISCONCEPTION:** TEL innovation should be focused on formal education.

Historically, government policy related to TEL has focused on formal education. In the 1980s, the Microelectronics Education Programme (see the boxed case study in Section 3) aimed to ensure that school leavers would be familiar with computers and their potential applications. In the 1990s, the Teaching and Learning Technology Programme provided impetus for adoption of TEL across the university sector. In 2005, the Department for Education and Skills report on 'Harnessing technology: transforming learning and children's services' included references to lifelong learning electronic portfolios and occupational training, but focused most of its attention on the formal sector [57]. In the same decade, the 'Strategy for e-learning' and





What's quite unique about Coventry is that they have this very large Business Development Support Office [...] What's good about that is that they know how to behave around industry and they know how to deal with industry and they know how to connect things together. And that's a huge advantage for Coventry because we have this very long tradition of working with industry and I think that's really made a big impact. //

**Sara de Freitas**

Founder of the Serious Games Institute at Coventry University

its successor 'Enhancing learning and teaching through the use of technology' published by the Higher Education Council for England (HEFCE) focused, as would be expected from HEFCE, on the higher education sector [58, 59].

Attention to informal learning has not been entirely absent. The Computer Literacy Project of the 1980s promoted public understanding of microelectronics technologies through the medium of television. Earlier this year, the Department for Business Innovation and Skills published a research paper on 'The maturing of the MOOC' that made recommendations regarding future research [60]. Nevertheless, most policy in this area has been concerned with the teaching and learning that takes place in schools, colleges and universities.

A related issue is that access to TEL research publications remains limited for those outside the university sector. Researchers working in business and industry have restricted access to research findings, and are therefore hampered in their ability to engage in evidence-informed innovation. While working on the Beyond Prototypes research study, a team member who works in the commercial sector was unable to access all the literature cited in the bibliography that appears at

the end of the report. Even some team members who had access to university library facilities found it difficult to locate some end-of-project reports.

During the past decade, the informal learning sector has emerged as an important area for large-scale commercial TEL innovation. Individuals are adopting open educational resources and mobile learning software on a massive scale. To take the example of just one provider, from 2008 to 2013 there were over 64 million downloads by around 9 million unique visitors of the open educational resources shared on iTunes by The Open University. Worldwide, there is an increasing demand for lifelong learning, for staff development and for on-the-job training opportunities.

Entrepreneurial universities, offering new methods of informal learning on a worldwide scale, have fuelled the recent explosive growth of MOOCs. In 2010, 200 students enrolled on Stanford's Introduction to Artificial Intelligence course. The following year, when it was made freely available online, 160,000 students from 190 countries enrolled [61].

Developments in the informal sector support developments in the formal sector. Universities are currently investigating how they can convert

informal learners into formal learners by providing pathways to enrollment and to qualifications. The success of Scratch is closely associated with the way in which socially supported informal learning acts as a bridge into formal learning.

**RECOMMENDATIONS:** In order to address the growing importance of the informal learning sector, policy and funding should support the experimentation that is necessary to generate fresh insights and achievable visions of educational developments. Research findings in all areas of TEL should be available to researchers both inside and outside the university sector.

### 5.3 Widen the TEL community

**MISCONCEPTION:** Specialized areas of expertise drive TEL innovation.

Research and development in learning with technology are fragmented, with separate communities for TEL, e-learning and computer-based training. Specialist research conferences have been established in many areas, including Computer-assisted Language Learning, Mobile Learning, Computer Supported Collaborative Learning, Networked Learning, Serious Games, Open Learning, Artificial Intelligence and Education, and Educational Media. Despite the work of the European Networks of Excellence in engaging a broad range of researchers, the TEL community is not able to speak with one strong voice.

A focus on establishing specialised communities of researchers means that less attention is paid to building links with learners, teachers, policy makers and industry. This means it is difficult to complete the innovation process because experience, expertise and visions of educational change are not widely shared, and

there are limited opportunities for understanding the ecology of practices within which innovations will be deployed.

Various initiatives suggest ways of broadening the TEL community and making links between research, teaching and industry. The BETT education show is currently developing a research strand. In addition, it encourages the sharing of best practice and teaching innovation by connecting with practitioner-run TeachMeet gatherings and hosting a large-scale TeachMeet each year. The Association for Learning Technology (ALT) works to improve practice, to promote research and to influence policy, providing a forum for researchers and practitioners in further and higher education. The series of 'What Research Has to Say' events organised by the London Knowledge Lab, the University of Nottingham, and The Open University has communicated new developments in TEL research directly to companies and policy makers. Other opportunities need to be found to integrate the disparate research and practitioner groups and the emphasis needs to be on dissemination by engagement with learning taking place by all parties, rather on dissemination by broadcast.

**RECOMMENDATIONS:** In order to widen the TEL community, researchers need to engage with the individuals and communities that will play a role in the implementation of innovations. Policy and funding should encourage the development of skilled, multidisciplinary teams that are able to complete the TEL innovation process.

## 5.4 Connect TEL research and practice

**MISCONCEPTION:** Most of the TEL innovation process takes place within universities.

TEL research largely operates at an elevated level and focuses on medium- to long-term innovation.

It is focused on universities, though this is hardly surprising, given that the funding for UK research comes mainly through the Research Councils and the European Commission. The focus in the forthcoming EC Horizon 2020 programme on small companies may help to shift that emphasis, but TEL is not a central theme in that programme.

The Mobile Learning Network (MoLeNET) programme of capital funding for further education (FE) institutions to embed learning with mobile technologies into FE was a good example of TEL research being embedded directly into practice. Training practitioners to become TEL researchers is not the solution because practitioners are already fully occupied – rather there is a need to form enduring partnerships between academic TEL researchers, practitioners in schools, colleges and workplaces, and innovative e-learning companies.

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## MISCONCEPTION: Scientific methods developed for laboratory research are the best way of evaluating the impact of TEL innovations.

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In order for TEL innovations to have long-term educational impact, they must be embedded successfully. In some cases, they are embedded within universities but, in most cases, they are deployed elsewhere. It is important to pay attention to and plan for this element of the process.

**RECOMMENDATIONS:** Policy and funding should take into account the importance of this stage of the innovation process and the need for extended development. There should

be capacity to support individuals and teams to engage in long-term projects capable of turning inspirational ideas into fully embedded products and practices. Researchers and developers should be encouraged to plan for sustainability and to identify the elements that must be taken into account in order to enable sustainable implementation of an idea or prototype, in the context of a vision of the enhancement of learning. The implementation and success of plans for sustainability should be evaluated.

## 5.5 Find new ways to assess the contribution of TEL

**MISCONCEPTION:** Scientific methods developed for laboratory research are the best way of evaluating the impact of TEL innovations.

'No significant difference' is an issue that has dogged TEL from its inception. It has been difficult to demonstrate a significant positive impact associated with the introduction of TEL into a classroom.

A major study in the form of a second-order meta-analysis of the impact of technology on classroom learning (a synthesis of the findings of meta-analyses, encompassing 1,055 research studies) found an effect size of 0.35 [62]. To put this in context, it is below an effect size of 0.4, which is the level at which the effects of innovation enhance achievement in such a way that real-world differences can be observed [62] and lower than the effect size of some other educational innovations, including

reciprocal teaching (0.74) and mastery learning methods (0.58).

The authors of the study indicate that simply measuring the effect of introducing technology misses the important point that it is how the technology is used that makes a difference. For example, effect sizes from computer technology used as 'support for cognition' were significantly greater than those related to computer use for 'presentation of content' [62]. The implication is that it is more helpful to examine the influence of a combination of innovative pedagogy and technology rather than technology alone. The way in which the innovation is introduced, including management support and teacher development, is also likely to influence the outcomes substantially.

Evidence-based practice is crucial for TEL because it ensures that learning is enhanced by technology in practice, as well as in theory. However, the methods for assessing educational impact have to be carefully chosen and appropriate to the innovation. Goldacre suggests that 'randomised trials are generally the most reliable tool we have for finding out which of two interventions works best' [63]. There are certainly cases in which this method can be used reliably. The large numbers of participants engaged in MOOCs allow comparative testing, in which randomly selected groups assigned to one of two conditions and the outcomes assessed quickly. This differs from randomized control trials, in being part of a process of rapid testing and development. In other situations, though, it can prove impossible to alter one or two variables while other factors remain constant. This is particularly true when TEL innovation involves changes to a series of interconnected practices.

Kirkwood and Price investigated what enhancement of learning means in the context of TEL [64]. They note that it is difficult to attribute causality when independent variables are not held constant; the comparative study method is only appropriate where other elements of teaching are replicated. A learning enhancement that is associated with the provision of additional resources or tools for one group of learners may simply be attributable to extra time spent on the task or extra teacher attention. If a study does succeed in replicating all elements of the learning experience other than the one being assessed, it is not necessarily clear what has been enhanced. Different evaluations of the same innovation can give different results, and the same results can be interpreted or presented in different ways as the Cognitive Tutor Software case study (see box) shows.

The comparative approach is associated with behaviourist views of learning, and makes the assumption that enhancement will be associated with quantitative change – improvement in test scores – rather than qualitative changes that are more difficult to measure, such as a richer or deeper understanding. An innovation that is tailored to meet the requirements of a randomised controlled trial may have to limit its scope, thus reducing its impact, in order to do this.

**RECOMMENDATIONS:** There is an urgent need to ensure that TEL innovation is evidence based and has demonstrable impact. In order to do this, policy and funding should require the evaluation of TEL innovations in terms of their educational impact. New methods of evaluation, such as the use of learning analytics or A/B testing where appropriate, should be developed and put into practice.

## 5.6 TEL success is not necessarily commercial success

**MISCONCEPTION:** Effective and sustainable TEL products and practices have commercial value and commercialisation should therefore always form part of the innovation process.

The assumption that innovation should be associated with commercialisation was built into the Beyond Prototypes study from the start. Each example of TEL innovation was considered in the context of challenges to commercialisation, assistance to market and relationship between impact and commercial exploitation. This analysis showed that, although very important in some contexts and for some projects, commercialisation is not an essential part of the TEL innovation process.

Innovation is not synonymous with invention and it is rare that TEL research produces an individual item of exploitable technology in the short term. University-led research is more likely to be focused on long-term educational impact than on commercial success. Academic researchers are recruited and trained to research the theory and science of learning. They are well placed to test and evaluate TEL innovations, because education is the core business of a university. However, they are not encouraged to create educational enterprises, which might compete with their university for students. Nor are they encouraged or resourced to replicate the role of an R&D unit within a large company.

The belief by many academics in open research and free access to learning does not necessarily fit well with a commercial imperative for profitability and return on investment. Publicly funded

universities have a strong motivation to share their research and development with the public that paid for it. Funders may reinforce this impetus towards openness by requiring that the results of research are made freely and openly available. However, trying to make everything open and free makes it hard for industry partners to build on and extend the work in order to make money. Some companies, such as Google and Facebook, have achieved commercial success based on ‘freemium’ models that provide free services or content and make money in other areas. However, many industry partners do not wish to take on the difficulties and risks inherent in the implementation of such models. There is a need for sustainable funding that can support both open research and commercial exploitation.

Academic TEL research has an effective role to play in contributing to the fundamental research and evaluation of design-based research partnerships that are put in place to develop new learning-technology systems. This is a larger-scale enterprise than developing individual pieces of software or carrying out small-scale evaluations. It requires coordination across institutions, involving academic, practitioner and commercial partners. This should not be an afterthought, but should be planned from the start of the project. Diana Laurillard, Professor of Learning with Digital Technologies, notes that

early association between academics and a company wanting to make a certain product is critical. The company needs to feel this is important for its future portfolio of products.

A partnership role, with the university as an investor or innovation partner (as with

## Case study: Cognitive Tutor software

Carnegie Learning has been a provider of innovative, research-based mathematics curricula for middle and high school students in the USA for over a decade and in 2012 was announced as the winner of the Software & Information Industry Association (SIIA) CODiE for Best Mathematics Instructional Solution. The company was founded in the 1990s by staff at Carnegie Mellon University working with practising teachers. In 2011 the Apollo Group acquired the company for \$75 million, with an additional \$21.5 million payable to the university for related technology.

Throughout this period there has been sustained debate around the issue of how adaptive learning software may enhance student learning. One focus has been on student test scores with some research noting little or no statistically significant change, other studies identifying significant impact, and some reporting mixed, anecdotal or selective data [65-69]. What is clear, however, is that a favourable perception can be bolstered by research and that this can influence purchasing decisions. However, it was found that the effectiveness of software was dependent on teachers’ ability to use it [70]. This required consideration of the complex of TEL elements, resulting in the development of materials such as textbooks, a recommended programme of teacher training, and pedagogy with greater emphasis on individual learning.

A recent comprehensive report by RAND on Cognitive Tutor has found that the cumulative effect can be that ‘treatment group teachers reported less implementation of traditional practices such as lecturing with students taking notes and greater implementation of more progressive practices such as facilitating student work or assigning students to work in groups and give presentations’ [68].

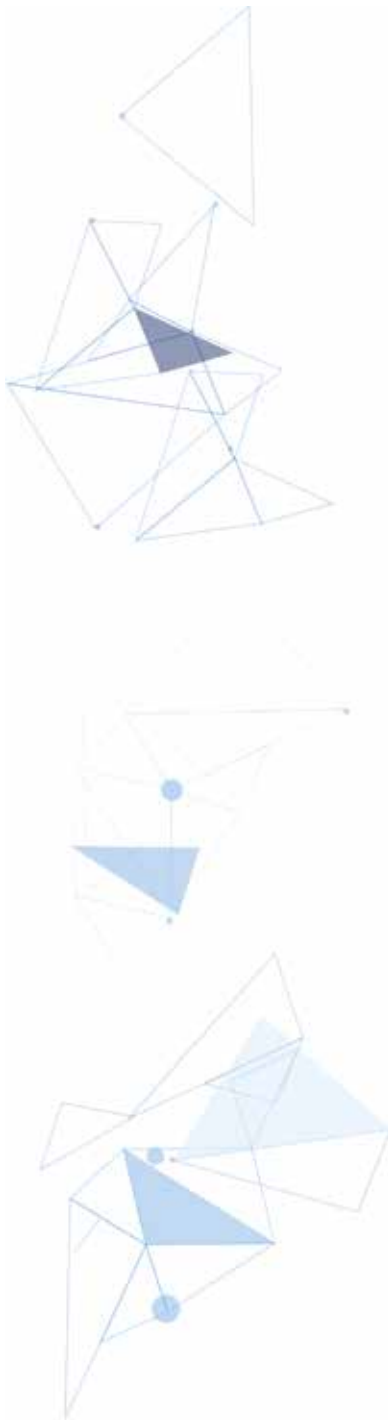
FutureLearn, currently partnered with 26 universities worldwide (as well as other institutions) or a long-term relationship between a university and companies (as with the Serious Games Institute) is likely to have more successful and sustainable outcomes than working on the assumption that universities are suppliers of TEL inventions. Firms need access to university expertise, but are unlikely to expect the key contribution of university researchers to be the production of new technology.

**RECOMMENDATIONS:** Where commercialisation is an issue, it should be taken into account when implementing the recommendations

made earlier. When project teams identify the elements that must be taken into account in order to enable sustainable implementation of an idea or prototype, in the context of a vision of the enhancement of learning, they should take the possibility of commercialisation into account. This requires engagement with the individuals and communities that will take responsibility for commercialisation. Policy and funding should encourage the development of skilled, multidisciplinary teams that are able to complete the TEL innovation process. If a commercial outcome is required, this should be specified from the start and the project team should include commercial expertise. ●

## 6 THE PROCESS OF TEL INNOVATION

Section 6 shows that TEL should be considered as a technology complex, made up of a series of interconnected elements that cannot be changed in isolation. A model of the TEL Complex is set out, centred on a vision of educational change. The TEL Innovation Process is also modelled and bricolage is set at its heart. TEL innovation should be evidence driven, and a core methodology is identified as design-based research.



### 6.1 The TEL Complex

Although, as Section 5 showed, TEL is rarely simply a product, a common tendency is to focus solely upon the technology element and its transfer into practice. This implicit assumption of a linear model of innovation often underlies the expectations of policy makers. It is typically assumed that processes of research, development and diffusion follow sequentially. Sometimes a phase during which opportunities or gaps in the market are identified may precede the research. Rothwell [71] provides a useful summary of different models of innovation, identifying two linear models: technology push and market pull. The merits and deficiencies of the linear model formed the focus of session held at a Nobel symposium in 2002 [72].

A study of 2000 cases of innovation by Keeley and his colleagues [14] provided a counterpoint to the simple 'kit' view of innovation. The study identified ten areas of innovation, including the processes involved in providing services, the services that provide value for customers, the profit model, the organisational structure, the product performance, the channel by which the services are delivered and the process of customer engagement. While innovation may take place in any of these areas, it often includes several working together. For example, an innovative form of customer engagement may require a new form of organisational structure. Although these areas of innovation are framed in relation to market-oriented business organisations

rather than TEL, together they capture the sense that innovation is generally complex and its successful achievement may involve changes to many different elements in a manner that is multiple rather than linear.

The Beyond Prototypes case studies show that TEL should be understood as a 'complex' comprising a series of components that need to be addressed together. A generic 'technology complex' includes a wide range of elements, including purpose, materials, procedures, knowledge, organisational structure, industry structure, location, social relations and culture [73].

In the case of the TEL complex, several key elements must be taken into account in order to develop and realise a vision of innovation. These are set out in the model in Figure 1, and considered in the paragraphs below.

**Pedagogy** is a crucially important component of successful TEL innovation and goes well beyond the technical elements used to support it. In terms of the areas of innovation identified by Keeley and his colleagues [14], pedagogy comprises an extremely complex and distinctive process which involves both student and teacher engagement, delivering a set of educational services by means of specific channels.

**Technical components** are the most visible components when considering innovation within the TEL Complex. They are the technological elements that are used to support the pedagogy with the aim of achieving

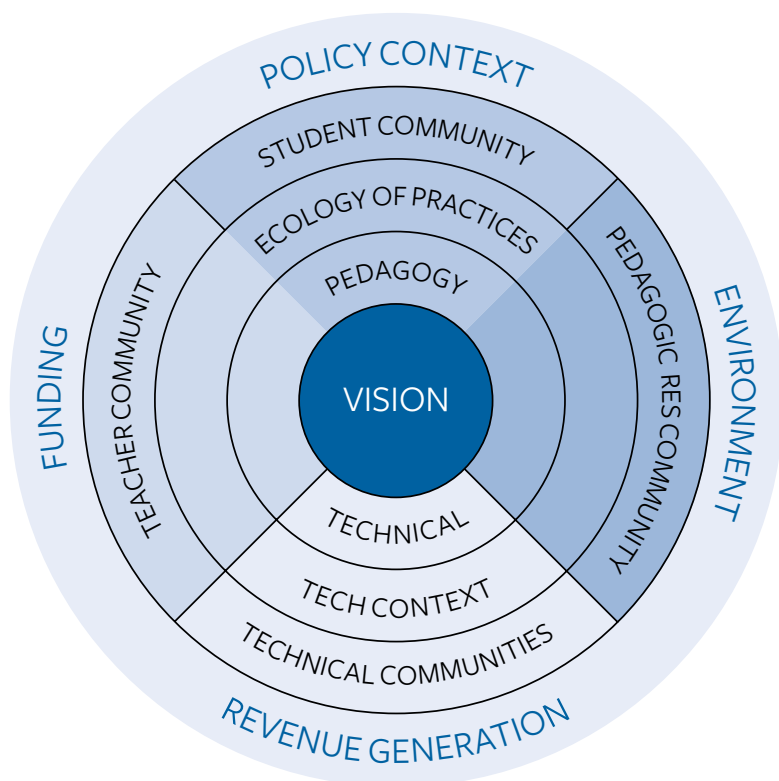
a vision that is concerned with enhancing learning in a specified way.

**The ecology of practices and technical context** must be taken into account, because any TEL innovation will be implemented in a specific ecology of practices. For example, the development of Yoza Cellphone Stories (see box) took into account the limited access to books experienced by some communities in South Africa as well as local practices associated with the use of mobile phones.

Current practices are not easily altered; they are at the core of super-stability in the overall educational system. In the TEL Complex, practices include explicit aspects of teachers' practice as well as the tacit knowledge acquired through extensive apprenticeship, training programmes and long experience. Students' practices are also crucial, and systematically relate to those of teachers. How students learn, both formally through structured teaching and learning programmes, and informally, through social and peer interaction, is important for the effective operation of TEL innovation.

In stable systems, innovation that involves changes throughout the entire ecology is characterised as 'system innovation'. Many different sub-components have to work together, with each subcomponent subject to the constraints of the overall system. These complex interdependencies make it difficult to get any one element to work or make a difference by itself without consideration of the whole [74]. Moreover, different components can combine and recombine in many different configurations. Ultimate success depends on the totality of the configuration or bundle, rather than on any single component.

**Figure 1: The *Beyond Prototypes* model of the TEL Complex**



**Communities** involved in the TEL Complex include students, teachers, researchers and those engaged in technical development. In literature dealing generically with innovation, these would be characterised as suppliers and customers. These four communities have others associated with them, including the parents of young

objectives and above all, expertise. This strong community presence within the TEL Complex constitutes a major challenge for TEL innovation, and in many cases exhibits super-stability, meaning that change is extremely difficult to achieve. In particular, current expectations of teachers and students affect the adoption of TEL innovations.

## Any TEL innovation will be implemented in a specific ecology of practices.

learners, the families of mature students, the managers of educational institutions and the people responsible for teacher training and technical support. The communities associated with these different sets of stakeholders often have different values, perspectives,

**The wider context (including policy, funding and revenue generation)** Although TEL is not typically a conventional market-oriented business example, there is always a need for sources of funding to initiate, sustain and support the processes of innovation



## Case study: Yoza Cellphone Stories

The aim of the Shuttleworth Foundation funded Yoza Cellphone Stories project (Yoza), formally entitled m4Lit, was to promote leisure reading by the distribution of m-novels to mobile phones in South Africa – a country where less than 10% of public schools have functional libraries but 70% of urban youth have internet-enabled mobile phones. The project began in 2009, taking inspiration from work done in Japan, using an existing mobile chat platform to release content and advertise, and publishing in local languages, including Afrikaans and isiXhosa, as well as English. Yoza considers the key innovation in this process of bricolage not to be the use of phones, but the provision of really engaging stories (some published in episodes), available easily and affordably, with readers able to comment and see others' comments in near real time.

In early 2013, Yoza won the Netexplo Award in Paris and had a catalogue of over 50 openly licensed m-novels, poems and plays, some of which deal with difficult subjects such as living with HIV. Use of the service has been strong, with over half a million completed reads and 50,000 user comments recorded in the 17 months to December 2012. Securing further funding has proved challenging. However, content has been reused elsewhere, including by Young Africa Live, and the model has helped pave the way for other initiatives in South Africa such as the FunDza Literacy Trust.

and development. This need for sustainable funding has recently been identified in the innovation literature as an associated 'business model' [75] which incorporates an 'earning logic' [76] or 'revenue mechanism' [77]. It involves, at the very least: (a) the provision of value, (b) the effective utilisation of assets or resources in providing that value, as well as (c) the securing of sustainable support through some form of revenue generation. In the case of TEL, if policy dictates that funding for TEL is subsumed within general educational budgets or within special project funding, then competition with regular demands or the time-limited nature of project funding can work against long-term sustainability and adequacy of support. This is important, because complex innovations typically require decades for effective diffusion.

The model of the TEL Complex illustrated in Figure 1 shows that, in order for innovators to develop and achieve a vision of TEL, it is necessary to engage with all these elements: pedagogy and technology, current practices and communities, the local ecology and the wider complex. This is a process of configurational innovation that requires research teams to engage in 'bricolage'.

## 6.2 Configurational innovation and bricolage

A central theme in the Beyond Prototypes case studies and interviews is that successful innovations in TEL are often not new inventions. They more often involve assembly of technological elements and practices, most of which already exist, into novel configurations, applied in new settings.

### 6.2.1 Configurational innovation

Technological innovations, like TEL innovations, often do not rest on new technological components but rather on the ways in which pre-existing and well-understood technologies are configured to meet new challenges. Fleck introduced the idea of 'configurational technologies' to describe and analyse the ways in which technical systems are created and configured to conform to the contingencies of specific applications. Local contingencies crystallise to form technological configurations [78].

Peine built on this work and used the case of Smart Home systems to show how learning and innovation develop in the application of configurational technologies [79]. The configurational nature of Smart Home technologies is inherent in the wide range of technological systems and expertise that must be brought together to create smart homes. It is also inherent in the need for these homes to work in the context of the local social practices and everyday routines of homeowners.

Both Fleck and Peine emphasise that configurational innovation arises from 'learning by trying', by which they mean active engagement in design and local experimentation in response to local practices. This places the stress on innovation as implementation.

There are important parallels here for TEL innovation, but this report goes further in stressing the role of practices as part of TEL innovations, not just as part of their context. TEL innovations are most readily understood as configurations, not just of technological components but also of social practices. As shown by the example of the interactive whiteboard in Section 5, relevant practices include, but are not limited to, pedagogical practices.

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## Although TEL research produces novel technologies and pedagogies, such work is only a small part of TEL innovation.

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Although TEL research produces novel technologies and pedagogies, such work is only a small part of TEL innovation and should be seen as just one component of broader configurational work.

### 6.2.2 Social practices as part of the TEL complex

The *Beyond Prototypes* case studies and interviews foreground the role that is played by social practices, not just as a context for TEL innovation but as important elements in the configuration of TEL innovations. For example, in Mitch Resnick's account of the development of Scratch quoted in Section 4.1, the importance of prior work on related technologies such as Logo is evident. However, a pivotal element of this case is the engagement with and understanding of children's informal learning practices in programming clubhouses, and the later appropriation of social networking practices to support social learning. Indeed, the principal innovation of Scratch lies less in the nature of the programming language than in the configuring of Scratch and a social platform to engage with the informal learning and social networking practices of young people that have emerged in relation to computer games.

Similarly, in the case of iZone (see boxed case study), existing technologies from motor racing, flight simulation, eye-tracking and sports science have been brought together with a particular set of coaching practices and a deep understanding of the practices of racing drivers.

*There's as much effort goes into training in this boardroom as*

*happens on the simulator. You know, when we first start, the hardest thing is to get people to accept that to be successful they've got to change their lifestyle. [Alex Hawkridge, chairman of iZone Driver Performance]*

The technologies afford new developments in coaching practices and these afford new ways of configuring the technologies.

The TEL innovation process thus involves many different stakeholders, all of whom are embedded in distinct communities with different expectations and understandings of TEL and of learning and teaching. Selected technical elements, specific pedagogic ideas and desired practices have to be pulled together into effectively working bundles, drawing on contributions from the disparate stakeholder communities. All these bundles of distinct elements have to be addressed in order for innovation to take place. This process can be characterised as *bricolage*.

### 6.2.3 Bricolage

The anthropologist Lévi-Strauss coined the word 'bricoleur' to describe someone who makes do with whatever is at hand. Bricoleurs do not typically start a project

and then consider which tools and materials will be required to achieve their goals. Rather, they review their available materials and tools and work out how to use them to achieve their goal or something close to their goal [80]. Above all, bricolage is rooted in engagement with the concrete properties of a situation and the available materials, rather than with an abstract model of how they will behave. For Lévi-Strauss, bricolage does not only apply to the material but also to the realm of ideas and social practices.

*The 'bricoleur' is adept at performing a large number of diverse tasks; but, unlike the engineer, he does not subordinate each of them to the availability of raw materials and tools conceived and procured or the purpose of the project. His universe of instruments is closed and the rules of his game are always to make do with 'whatever is at hand', that is to say with a set of tools and materials which is always finite and is also heterogeneous because what it contains bears no relation to the current project, or indeed to any particular project, but is the contingent result of all the occasions there have been to renew or enrich the stock or to maintain it with the remains of previous constructions or destructions. [81:11]*

Lévi-Strauss described bricolage as characteristic of primitive societies and contrasted it with a scientific

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**The 'bricoleur' is adept at performing a large number of diverse tasks; but, unlike the engineer, he does not subordinate each of them to the availability of raw materials and tools conceived and procured or the purpose of the project.**

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## Case study: iZone Driver Performance

iZone was set up in 2009 to address a change in Fédération Internationale de l'Automobile (FIA) regulations, which reduced racing teams' testing time. While test equipment and simulators for the testing of cars and components were already used, nothing was available that could replace track time for drivers. Sophisticated simulators with video screens had been developed over the previous 35 years, but much more complex systems, able to provide physical feedback such as g-forces, were required for the development of elite drivers.

iZone addressed this problem by interlinking physiological systems and electromechanical systems. It uses eye-tracking technology to enable coaches to analyse drivers' performance and assess their control during the simulation. This technology was developed by the company's simulator designer, John Reid, who was inspired by an article about the use of eye-tracking systems in helicopter gunships.

iZone has links with Cranfield Aerospace that stretch back to the 1980s, when company chairman Alex Hawkrigge used the wind tunnel at Cranfield to develop the aerodynamics of Toleman F1 cars. The company now uses the g-force technology from Cranfield's helicopter trainer and also has PhD students from Cranfield working with the company on aspects of the project. A similar long-term relationship with the Department of Electrical Engineering at the University of Sheffield has also helped with the development of the simulator.

Based on work with racing drivers prior to setting up iZone, the team has created a training regime developed by sports scientists and sport psychologists to offer a complete driver development programme that includes the use of the simulators. The sport psychology input came from Dave Collins, who had developed a name for coaching and mentoring in athletics and football as well as in motorsports.

Most technology businesses are concerned with the protection of intellectual property (IP), but Alex Hawkrigge's view is that, 'the things that are patentable, we don't think it would be wise to patent, because you then tell people exactly what you're doing.' He considers that the most important way to protect the business's IP is to keep developing the simulator business. The potential for iZone to run a similar operation at every major racetrack in the world is a real opportunity; a future way forward might include franchising the model in order to maintain its speed of development.

approach in modern societies. However, subsequent authors have built on his work to show the importance of bricolage to areas of current society as diverse as scientific endeavour [82], product design, entrepreneurship [83, 84], social entrepreneurship [85], financial economics [86] and the enactment of social change [25]. These streams of research have drawn on the notion of bricolage in order to understand how innovation and change come about through the creative reinterpretation and arrangement of existing social practices and resources, and how this process enables new possibilities within the constraints of existing social systems and institutions.

### 6.2.4 Bricolage and 'persistent intent' within the TEL space

Bricolage is a core theme that has emerged from the Beyond Prototypes study. The narratives produced by case studies and interviews reveal successful TEL innovators not simply as inventors or as scientists proposing and testing hypotheses but also as bricoleurs who achieve educational goals by bringing together diverse technological elements, frameworks and social practices. The ultimate success of TEL lies in the implementation of the entire 'TEL Complex' modelled in Figure 1. However, much innovative work fails to be implemented, because it does not take the complex into account.

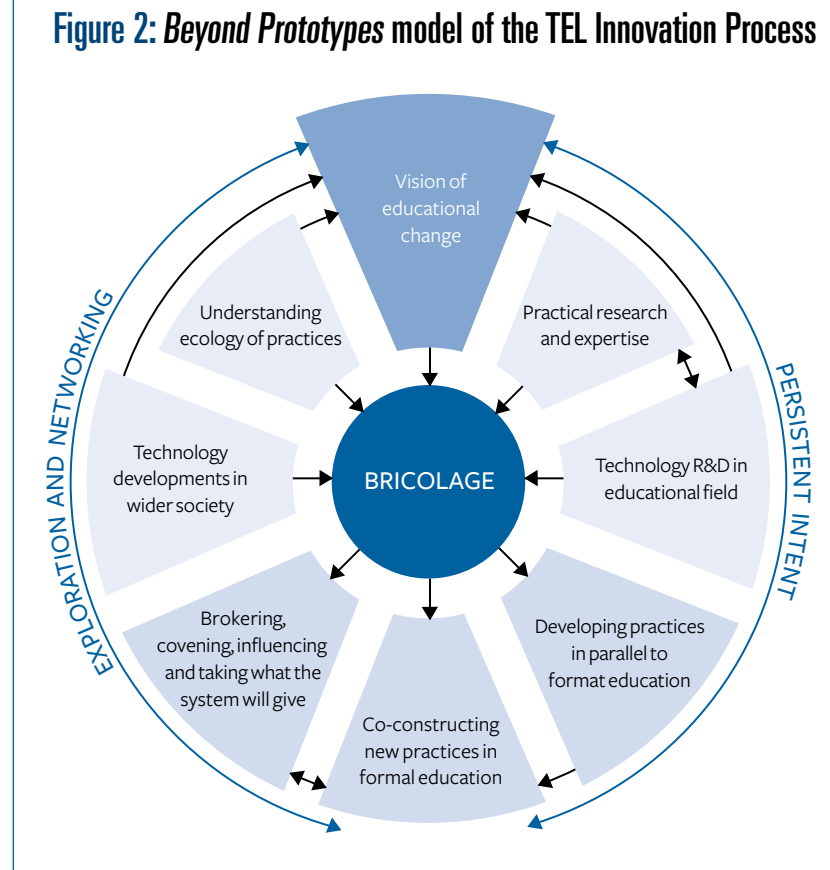
*A research group is not equipped to take on all the other factors that are required in order to scale, to move from a research project or pilot to a scaled one [...] They are lulled into thinking that when they have a successful pilot the next step will be easy. The next step is the hardest step of all. When they go to schools with their piece of kit and their wonderful technology [they fail because] other factors such as curriculum, professional development, sustainability and appropriateness are not taken into consideration [Elliot Soloway, founder of the Center for Highly Interactive Computing in Education]*

Each element of the complex requires explicit and careful consideration in order to avoid failure and maximise chances of success. This process of TEL bricolage does not take place at a single point in the process of innovation process but extends throughout the process. TEL innovation, as is typical for any complex example, can require decades for full diffusion and during that time researchers engage in bricolage as they work towards their evolving vision of the development of learning and teaching. This involves not only the combination of resources but also the development and assembly of a stock of resources, in addition to the development of a close understanding of the nature and affordances of what is at hand [87]. This process lies at the heart of the TEL Innovation Process.

### 6.3 The TEL Innovation Process

Literature based on extensive experience in various business settings illustrates that multiple factors and issues have to be attended to in order for a new technology or practice to be employed effectively within a complex. Many authors have observed this fundamental characteristic of the implementation of innovation, yet it is nearly always overlooked when new technologies are developed [See, for example, 14, 73, 88, 89-91]. In the context of innovation in educational multimedia, Van Lieshout and his colleagues have identified innovation as a process of 'social learning' [92].

Figure 2 presents TEL innovation as a process of bricolage that involves the assembly of technological elements and social practices to inform a complex process of innovation that has the aim of achieving educational goals. As noted above, while the invention of new technological elements or pedagogic approaches may be a component of such innovation it is



by no means a necessary condition. Some elements from that process are expanded below, along with a design methodology that encompasses the entire TEL Innovation Process.

#### 6.3.1 Vision of educational change

Generating change in educational practices that is more than local

Instead the vision often emerges and evolves through exploration, through networking and through active engagement in research, development and educational practice. Visions of educational change are co-created through engagement with different aspects of the TEL Complex.

**Vision often emerges and evolves through exploration, through networking and through active engagement in research, development and educational practice.**

and temporary is difficult to do and demands persistent intent over time. This, in turn, requires a clear vision of what could and should be achieved. However, the Beyond Prototypes case studies and interviews show that a clear vision is rarely the starting point for the innovation process.

#### 6.3.2 Pedagogical research and expertise

Engagement in research into educational technologies and pedagogy has an important role to play in TEL innovation. The direct products of this research are important but so too are the

**It is important that this TEL Innovation process is aligned with a research model that supports evaluation of what has been achieved, and that can build on previous findings.**

connections and expertise that are created during the research process. The Beyond Prototypes study also highlights another crucial form of research. This is research that is aimed at understanding the ecology of practices with which a particular TEL innovation must engage. Examples from the case studies included in this report include young people's relationships to storytelling practices in the Yoza case, financial traders' trading practices and learning practices in relation to xDelia, and children's social networking practices in relation to Scratch.

### 6.3.3 Developing practices in parallel to formal education

Because it is difficult to achieve rapid and significant innovation within formal education sectors, successful innovations may impact first on informal learning practices. In some cases, this can provide a platform for translating the innovation into formal education.

To take one of the TEL successes described in Section 4 as an example, Scratch is a complex made up of software, hardware platform(s), informal learning practices, social learning practices, as well as many other elements. This TEL complex is enacted within an ecology of practices that includes elements such as software security practices and the friendship networks (online and offline) of the target audience in its initial informal learning instantiation. In this case, it was initially enacted within the context of a specific ecology of informal

learning practices. Increasing public and political concern about school leavers' lack of programming skills has created opportunities to translate the use of Scratch into formal learning contexts. In the process it becomes something new. Scratch as a TEL complex is different when enacted in an informal learning setting to its enactment in a formal learning setting and the process of translating the complex from one setting to another is non-trivial.

### 6.3.4 Co-constructing new practices

Researchers bring models and theories of learning to the innovation process. These are refined through working with teachers and learners, together developing an understanding of how the ecology of the educational setting impacts upon these models and theories. This co-construction

means that researchers and practitioners can come, over time, to mutual understanding and respect for the ways in which theory-informed TEL can be enacted in real classrooms and other educational settings.

A notable consequence of the complexity of TEL, representing a major developmental opportunity, is that there is scope for 'user-driven' contributions from both teachers and students. Making use of these contributions requires engagement with users and a willingness to accept initial proposals that are sufficiently unfinished or unpolished to allow for effective intervention and ownership to take place. Such engagement may also be a necessary condition to properly understand the ecology of practices that will be the context for any particular TEL innovation.

In order to ensure that TEL innovation is evidence driven, it is important that this TEL Innovation process is aligned with a research model that supports evaluation of what has been achieved, and that can build on previous findings. A core methodology is therefore design-based research.

**Table 1: Comparison of design-based research with experimental studies**

Experimental studies	Design-based studies
Laboratory studies	Real-world situations that contain limitations, complexities and dynamics
Aimed at testing hypotheses	Aimed at designing new interventions and generating hypotheses
Usually single dependent variable	Multiple dependent variables (though not all are investigated)
Control of variables, through specification of fixed procedures	Iterative and flexible revisions of the research design
Typically isolated from the social world	Typically involve social interactions
Researchers are the decision makers	Partners contribute to the decision making

### 6.3.5 Methodology of Design-Based Research

This methodology has been developed over the past two decades and stems from ground-breaking work by Collins [93] and Brown [94]. These researchers developed the idea of design experiments when they found that traditional laboratory experiments were not sufficient to address the questions of interest to them.

The Design-based Research Collective asserts that ‘design-based research, which blends empirical educational research with the theory-driven design of learning environments, is an important methodology for understanding how, when, and why educational innovations work in practice’ [95]. Barab and Squires explain that

*design-based research [...] was introduced with the expectation that researchers would systemically adjust various aspects of the designed context so that each adjustment served as a type of experimentation that allowed the researchers to test and generate theory in naturalistic context [96:3].*

Wang and Hannafin describe the approach in more detail as

*A systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories [97:6].*

In many projects this involves iterative cycles of designing pedagogy and technology, running an inquiry, and then carrying out evaluation and analysis that feed into the next cycle. In this way, some of the key findings

of the research are embedded within the system: not only in the design of the software but also in how it is used by a growing and developing community of practice.

Schoenfeld writes of the way in which design experiments work.

*Properly construed, a design experiment consists of the creation of an instructional intervention on the basis of a local theory regarding the development of particular understandings. The intervention is then examined with regard to the accuracy of the underlying local theory and the power of the intervention, with an eye*

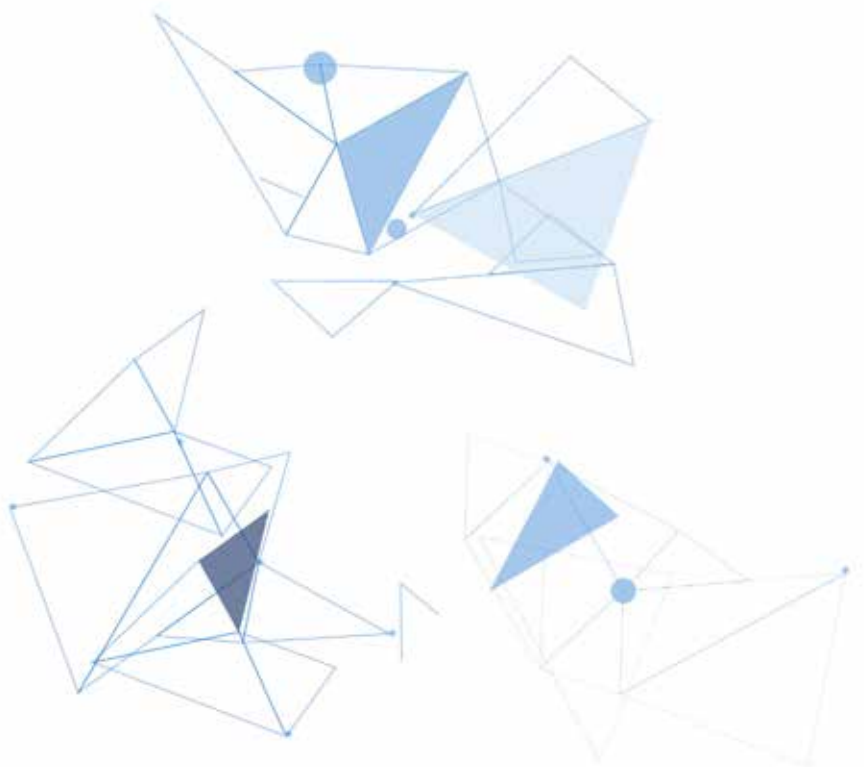
*toward refining both. Doing so thus calls for having a solid theoretical perspective and for possessing design skills, two talents rarely found in one individual. This raises the issue of design teams as part of the research endeavor [98].*

Table 1 compares design-based studies with more conventional, laboratory-based experimental studies. The experimental model works well when researchers are able to control the process of the research and isolate individual variables. The design-based approach aligns better with the model of the TEL innovation process that is set out in this report. ●

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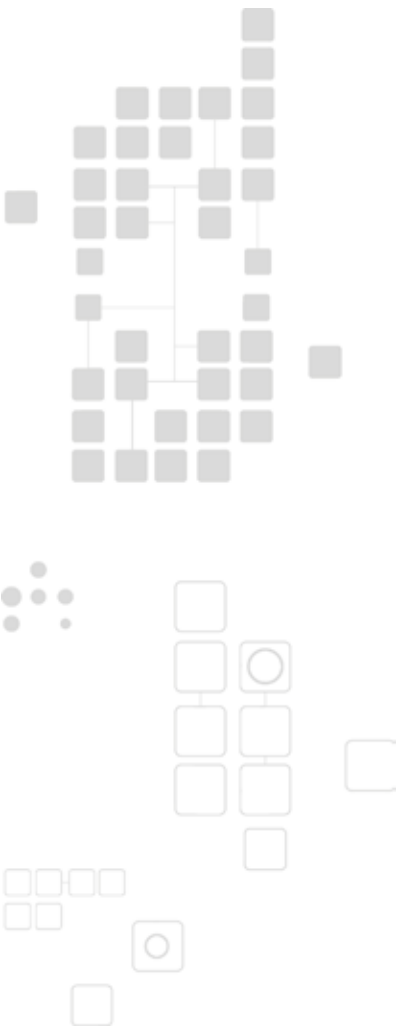
**A design experiment consists of the creation of an instructional intervention on the basis of a local theory regarding the development of particular understandings.**

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## 7 IMPLICATIONS FOR RESEARCH

Section 7 examines the implications of this report for research. Persistent intent, engagement over time and the use of an appropriate methodology are identified as priorities. Successful research also requires engaging with the practices and stakeholders that must be taken into account if research-informed innovation is to be embedded in practice.



Previous sections have set out how the TEL Innovation Process takes place, key elements of this process and recommendations for the future. This section examines the implications of these elements for researchers.

As significant TEL innovation takes place over an extended period of time, persistent intent on the part of any research team has been identified as crucial. Imogen Casebourne, Director of Learning at the Educational Program Innovations Center, traced the evolution of mobile learning from initial research in the 1990s, through the time when her company started working in the area, to the present day:

*We started creating mobile learning about 10 years ago ourselves, using PDAs [personal digital assistants]. It was only a few unusually forward-thinking clients for a very long time, who were interested in exploring it. Whereas, obviously, in more recent years it has really taken off.*

The same extended development process has taken place with computer-supported collaborative learning. Seb Schmoller, Chief Executive of the Association for Learning Technology between 2003 and 2012, provided an overview of the growth of this area, illustrating that the TEL innovation process can take decades. Significantly, he suggested that the timescale for this process can be so extended that original research is forgotten or under-utilised, indicating a need for persistent engagement and intent over extended periods of time:

*15 years ago, there was a research field, though 'field' is perhaps too wide a term for it, which was*

*concerned with computer-supported collaborative working, CSCW. I think a lot of the thinking and findings of CSCW research are very relevant now, because the tools and systems to support computer-supported collaborative work are now ubiquitous, which they weren't when the research was being done. When the research was being done, a lot of effort had to be put into designing and sustaining the tools and services in order for the research just to happen. Now the communication tools and systems are everywhere, but the kind of ideas that CSCW research threw up, I think to some extent have lain dormant, and are not properly utilised. Because lots of people coming to this technology enhanced learning afresh now don't realise that there's a back story of work that is very important.*

The eventual line of development, and the vision of innovation, is not always clear at the start. Early research may explore the affordances of a set of technologies – such as mobile devices or online conferences – or may investigate how technologies can be used to support a particular pedagogic approach. When Seymour Papert worked in the 1970s and 80s on 'creating the conditions under which intellectual models will take root' [36], there was no technology available that could enable the development of a programming language to be used collaboratively and synchronously by children across the world. Nevertheless, his work on constructionism and on programming with children deeply influenced Mitch Resnick, and has informed his team's development of Scratch at MIT during the last decade.



Another way in which TEL innovation extends over time is in the tension between creative and practical approaches. Early research may employ ‘catwalk technologies’ that demonstrate an exciting new concept but that are also costly, difficult to maintain and often impractical for extended use [99]. Successful mass exploitation requires a ‘ready-to-wear’ system that can be used off the shelf without problems. Researchers therefore need to take into account how this shift will take place, who will carry it out, and how it will be funded.

Engaging with user communities from the start has the potential to make them genuine stakeholders in new knowledge. The Epic Learning Group, a global provider of learning technologies, takes a consultative approach; staff work as partners or advisers with customers in order to develop appropriate and affordable solutions. Jeffrey Lins, head of research and innovation at Saxo Bank and a member of the xDelia consortium, stresses that it is important for companies to take some degree of ownership of research and development, so that these are not disconnected from implementation.

***We designed a project [XDelia] that was aimed at a particular ecosystem. We knew it existed; we didn’t theorise that it would exist sometime somewhere, or did exist somewhere. We knew it existed, we knew basically what that ecosystem was about and I think we had a clear vision for how we connected into that ecosystem. And that was a lot of the power of the project. [Jeffrey Lins, head of research and innovation at Saxo Bank]***

Continuing engagement helps researchers to gain an understanding of the environment in which their work will be implemented, and to be clear what has to happen before an innovation can be applied in practice.

Diana Laurillard, Professor of Learning with Digital Technologies (LKL):

***You improve the impact of an innovation by looking at what are the drivers in education, what makes people sit up and worry, and it’s funding flows, it’s curriculum requirements, it’s assessment and it’s quality.***

This work on understanding the environment is crucial. Seb Schmoller of ALT noted that, ‘If your organisation wants to do things differently, you need to do them differently in a way that will work within the rules and frameworks that govern the ‘ecosystem’ you are in. It’s easy to try to do things that ultimately just won’t work because they do not conform to those rules and frameworks’. A technology is unlikely to result in significant change unless it is connected with shifts in pedagogy and practice. Steve Vosloo, senior project officer in mobile learning at UNESCO, observed

***I have seen many cases where computers are put into a school or into a computer lab and the teaching, the learning, the whole paradigm, has not changed at all. The only thing that’s different is that it’s being done through a keyboard, and not on pen and paper.***

An important role for researchers within the TEL innovation process is to ensure that research is evidence based. This means employing a methodology that is appropriate to the process. Section 6.3.5 identified design-based research as a key approach. However, other new possibilities are opening up as technology-enhanced learning expands its scope. Learning analytics, ‘the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs’ [100], provide actionable

intelligence that can provoke or encourage practical action [101]. These analytics help educators and learners ‘to increase the degree to which our choices are based on evidence rather than myth, prejudice or anecdote’ [102]. The large numbers of participants in MOOCs allow rapid cycles of A/B testing in which users are randomly exposed to one of two variations of a TEL innovation – control A or treatment B – with changes in outcome explained by this assignment, leading to insights for further development [103]. The development of one TEL innovation may require the use of many methods.

## 7.1 Recommendations for researchers

- Research teams should identify, at an early stage, the steps required to enable scalable and sustainable implementation beyond prototypes, so as to enhance learning.
- Researchers need to engage fully with the individuals and communities that will play a role in the implementation process.
- Research teams should consider adopting Design-Based Research as a systematic but flexible methodology for research-led innovation, based on collaboration among researchers and practitioners in real-world settings.
- The interim and final results from design-based studies should be systematically shared with other researchers so that the process of innovation can be compared, expanded, and continued over time. They should also be widely disseminated to policy makers and practitioners, through events such as ‘what research says’ meetings.
- Research institutes should set up long-lasting collaborations and consortia, involving schools, museums and other educational settings as test-beds, to support large-scale comparative and cross-cultural investigations. ●

## 8 IMPLICATIONS FOR POLICY AND FOR FUNDING

Section 8 examines the implications of this report for policy and for funding, identifying current problems, particularly in relation to sustainability, and proposing solutions.



Some past policy initiatives have supported the TEL innovation process well. The Microelectronics Education Programme, established in 1980, ran for six years with the aim of preparing children for a world in which microelectronics would be commonplace and pervasive. Coupled with an initiative that made money available for schools to buy computers, this policy drove a well-structured process of TEL innovation that extended over time and took into account the changes necessary throughout the TEL complex. During the 1990s, the Teaching and Learning Technology Programme provided impetus for the adoption of TEL across the university sector. As with the MEP, this programme took into account the different elements of the TEL complex and was therefore able to provoke change across the educational system.

learning and computer-supported collaborative learning, such projects can build over a period of years into a body of work that is used to transform learning and teaching. However, this is an uncertain process of development that is not ideal. Impact outside academia would be supported by changes to current funding models in order to support long-term engagement and sustainability.

Seb Schmoller of ALT identified a significant problem with externally funded projects:

*I will stand more chance of successfully innovating if I try to innovate within the general constraints and parameters under which I and the organisation are expected to operate, rather than by making use of some temporary external funding that can be used to stimulate activity; because once the funding dries up the stimulus is removed and the activity ceases.*

**A project makes a short-term difference but then the funding runs out. Without support and maintenance, the successful innovation begins to wither.**

A project makes a short-term difference but then the funding runs out. The research and development team disbands and moves on to other funded projects. Without support and maintenance, the successful innovation begins to wither. At this stage, it is not clear how the work should be taken forward. One option would be to move towards commercialisation, but this presents several problems. As Section 5.6 explained, TEL success is not necessarily commercial success.

No such system-wide initiative is currently in place; the closest equivalent is the move to introduce programming within schools through changes to the curriculum. The current research funding system within the UK is not aligned with the TEL innovation process, though it is well suited to supporting short- and medium-term projects capable of producing results and academic publications that help universities to build a strong submission for government audits such as the Research Excellence Framework (REF). In some cases, as with mobile

At the most basic level, there may be nothing to commercialise. A change in pedagogy or practice is unlikely to be a marketable commodity; a new technology without a change in pedagogy or practice is unlikely

to have a significant impact. If the research project does result in a potentially marketable innovation, it is unclear who should take that forward. The primary role of universities is not to market products. Researchers are not trained in marketing and are not recruited for their entrepreneurial vision and spirit. As individuals, they may not have the skills, the interest, or the legal right to take an innovation developed by a team any further. They may also be limited in their choice of business model by funders' requirements that their work should be freely and openly available.

A better option is to ensure that the innovative development is sustainable. In order for this to happen, the project must have engaged people who are willing and able to support its continued success. The success of the Scratch project, for example, is strongly connected with its development of online and face-to-face user communities. On a smaller scale, organisations and individuals need the sense of ownership that comes from working closely with researchers in order to develop an innovation that works in context. This may not be an artefact. As Steve Vosloo, senior project officer in mobile learning at UNESCO, notes:

*You can look at other facets of the broader learning experience. There is some administration that needs to happen, there is some assessment that needs to happen, there is content to be delivered. Perhaps technology can help speed up the assessment process or the administration process. This is not learning, per se. But it creates a more efficient whole experience that could allow the teacher or the learner more time to actually teach and learn. So it's a kind of system strengthening or efficiency-improving measure. But if you only think of the learner and the learning experience, you don't get that.*

A funding package that focuses solely on the development of an artefact cannot adequately support this process. Focused, persistent intent is needed in order to encourage teams of researchers to extend and develop their work over time, with a shared goal in mind. Persistent intent has the potential to focus researchers' attention on the context in which their work takes place, encouraging them to develop the skills necessary to work with people in different contexts and bridge the gaps between them.

Knowledge transfer partnerships have a role to play here. However, they currently stress 'the transfer of knowledge, technology and skills to which the company partner currently has no access' [104]. There is less emphasis on the non-financial benefits gained by the university partner. Jeffrey Lins, head of research and innovation at Saxo Bank, commented that

*the boundaries have to be blurred, and that comes from respect on both sides. Commercial entities need to realise that universities actually do understand that things cost money, and how the business world works and what customers are like and these kind of things, because they do, and they model these things and they are intensely interested in understanding them. On the other hand, universities have to understand that there's a lot of competent research, researchers and research capabilities outside their walls.*

The commercial partner is crucial in providing the ability to contextualise a problem and to understand its ecology. At the same time, universities offer ways of reframing problems and identifying new perspectives. There is knowledge on both sides of the partnership that needs to be translated and transformed.

## 8.1 Recommendations for funders and policy makers

- Policy and funding should support innovations in pedagogy and practice, as well as the technological developments that will support these. This should recognize the need to fund professional development of practitioners and evaluation of the innovation in practice.
- Policy and funding should recognize the importance of extended development and provide support for scaling and sustaining of innovations, beyond prototypes into educational transformations.
- Policy and funding should encourage the development of skilled, multidisciplinary teams that are able to complete the TEL innovation process. Recognition and support should be given to visionary thinking and experimentation, to generate fresh insights and achievable visions of educational developments.
- There is a need to build research capacity in TEL within the UK. The research councils should give a clear indication as to where TEL proposals should be submitted, and ensure that proposals are reviewed by people with appropriate expertise in TEL research. Evaluation criteria should include successful implementation of plans for scaling and sustainability.
- Funders should provide support to research teams to evaluate their innovations for educational impact and transformation, through appropriate qualitative and/or quantitative methods. New methods of evaluation, such as learning analytics should be encouraged.
- Findings must be made available to other researchers and developers, including those without access to university libraries, so that the results of research and development can be used to continue and complete the innovation process. ●



## 9 CHALLENGES AND OPPORTUNITIES

Section 9 focuses on the way forward for TEL research. It identifies a continuing need for sustained building of capacity in TEL, through graduate programmes and investment in national hubs of expertise that share talent and facilities.



Education is a major export for the UK economy, estimated to be worth £17.5 billion in 2011 [105]. Technology for learning now forms an integral part of that educational export market, including direct income from publishing of e-books, online learning, and educational software, plus indirect benefits from competitive advantage in MOOCs, educational analytics, online learning resources, and blended and mobile learning.

As this report has shown, research associated with technology and learning has influenced and been influenced by other sectors, resulting in some surprising benefits to the UK economy. Arm Holdings, the major British semiconductor and software design company grew out of the work in the 1980s by Acorn computers to build the BBC Microcomputer as part of the Microelectronics Education Programme. During the same period, thousands of teenagers learned to play and to program games on

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**Research associated with technology and learning has influenced and been influenced by other sectors, resulting in some surprising benefits to the UK economy.**

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This innovation needs to be continually refreshed in order to maintain a competitive edge in the combination of technology and pedagogy. A year ago there was no major UK investment in massive open online learning. Now, 23 UK universities have made a substantial strategic commitment to the FutureLearn company. They are offering free education to hundreds of thousands of people worldwide, in part as a means of attracting overseas students to register for UK degree courses. The pace of change may be quickening, as education enters a similar period of disruptive innovation to that faced by the entertainment and banking sectors ten years ago, and as the nation develops its understanding of how to develop effective learning with technology at large scale.

microcomputers such as the Sinclair Spectrum, developing talent that initiated the UK computer games industry. At the same time, The Open University was developing its distinctive approach to supported online learning that combines computer-delivered materials with human tutorial support.

Now there is an opportunity for similar confluences of research-led innovation in learning and technology, around massive online learning, mobile learning, haptic technologies for learning, learning design, learning analytics, technology-based science, maths and computing education, interactive e-books and multimedia educational publishing. Some of these are altering traditional sectors such as publishing and universities; others are opening new business opportunities in educational software



The continuing need is for neither abstract grand challenges nor short-term initiatives, but for a sustained building of capacity in technology-enhanced learning, through graduate programmes and investment in national hubs of expertise that share talent and facilities. //

applications, and technologies such as haptic simulators.

These developments are fundamentally interdisciplinary. They can only take place through the combined efforts of topic specialists, technologists, and experts in teaching, learning and assessment. The UK still lacks expertise in the linking discipline of educational technology. The continuing need is for neither abstract grand challenges nor short-term initiatives, but for a sustained building of capacity in technology-enhanced learning, through graduate programmes and investment in national hubs of expertise that share talent and facilities.

To compete with other national TEL centres such as SRI International in the USA, Nanyang Technological University Singapore, National Central University Taiwan, and École Polytechnique Fédérale de Lausanne in Switzerland, the UK needs to pool resources across universities active in TEL research, involving innovative companies and partner schools,

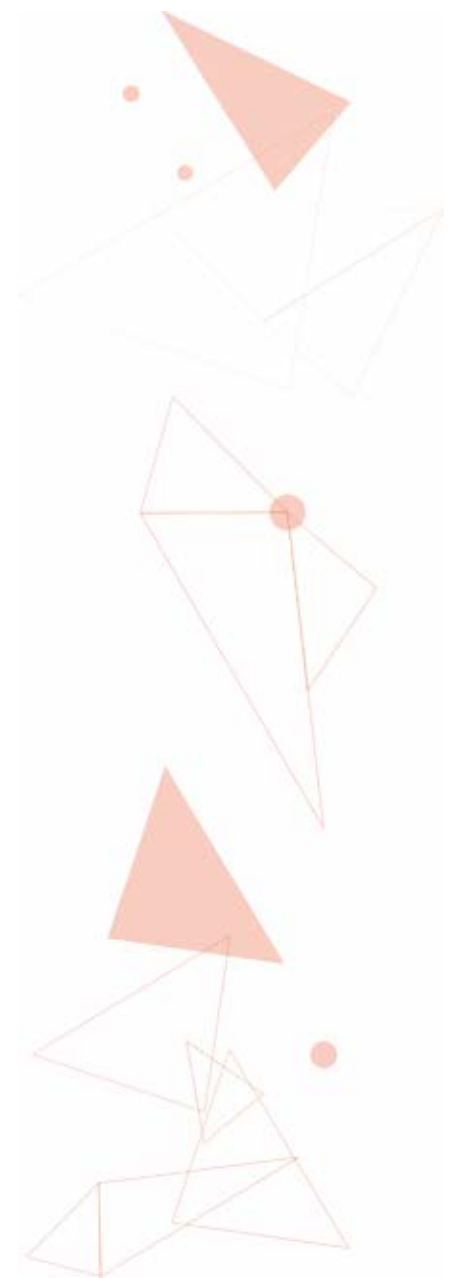
colleges and museums. The prize will be a sustained ability to do 'big R&D' that develops substantial educational systems over a prolonged period and evaluates them with a range of learners in informal and formal settings.

The focus for future TEL research should be on effective transformation of educational practices, rather than small incremental improvements, and on how these transformations can be scaled and sustained. We need to design new forms of learning that people (teachers, students and informal learners) want to adopt and use. The evidence presented in this report shows that research-led innovation in TEL is a complex process; the big successes cannot be predicted but they can be nurtured through a supportive environment that co-constructs learning and technology, supports the persistent intent of visionaries, subjects educational innovations to systematic evaluation, and partners with innovators in the education sector and in creative industries. ●

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**The focus for future TEL research should be on effective transformation of educational practices, rather than small incremental improvements.**

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## Research team

**Professor Eileen Scanlon** is Regius Professor of Open Education and Associate Director of Research and Innovation in the Institute of Educational Technology at The Open University. She has extensive research experience on educational technology projects in open education, science learning and evaluation.

**Professor Mike Sharples** is Professor of Educational Technology at The Open University. He has over 30 years of experience in bridging research and exploitation of TEL, through projects with British Telecom, Racal, Kodak, Microsoft, Nokia, Sharp and FutureLearn.

**Professor Mark Fenton-O'Creevy** is Professor of Organisational Behaviour with the Open University Business School. He is a senior fellow of the HEA and a National Teaching Fellow, with a recent track record of successful commercialisation of a major TEL project, the EU FP7-funded xDelia project.

**Professor James Fleck** is Professor of Innovation Dynamics at the Open University Business School and has researched innovation (most recently in e-learning) for 30 years, focusing specifically on issues of practical implementation. He was a member of the Academic Panel for the DTI/HTM Innovation Policy Review chaired by Lord Sainsbury.

**Dr Caroline Cooban** is Development Director at The Mighty Creatives, a creative development agency for children and young people, working across formal and informal settings. She also has over 15 years of experience of university research business development and knowledge transfer in the field of educational and learning technologies.

**Dr Rebecca Ferguson** is a lecturer in the Institute of Educational Technology. She has worked as research lead on educational technology projects including SocialLearn and EnquiryBlogger. Previously, she worked as editor and journalist on a range of publications, including the Radio Times.

**Dr Simon Cross** works in the Learning and Teaching Development Team in the Institute of Educational Technology. He has worked in research and coordination roles on external and internal projects with a focus on the open online learning space, learning design implementation and practice, badges and assessment.

**Peter Waterhouse** has worked in a variety of educational and business roles with particular experience in TEL, within both academia and industry. He has graduate qualifications in marketing as well as teaching and learning.





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London Knowledge Lab  
Institute of Education  
University of London  
23-29 Emerald Street  
London, WC1N 3QS

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